DNA 3467H

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE EARTH'S ATMOSPHERE

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This publication is a pocket-sized extract of information contained in "The Reaction Rate Handbook" (DNA 1948H), Revised Edition, and other sources, and is a compendium of useful data for the convenience of atmospheric chemists, physicists, etc.

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PREFACE

This Manual is intended to provide a pocket-sized compendium of current available knowledge concerning the physical and chemical properties of the earth's atmosphere. It has been derived principally from the Defense Nuclear Agency's "Reaction Rate Handbook (Revised Edition)", DNA Publication 1948H, and from other sources, annotated within each presentation according to a letter code, as follows:

Code B - Courtesy of Bell Telephone Laboratories.

Code E - From: Aids for the Study of Electromagnetic Blackout, W.S. Knapp and P.G. Fischer, DASA 2499 (1970).*

Code L - Courtesy of Lockheed Palo Alto Research Laboratory.

Code R - From: DNA Reaction Rate Handbook, Second Edition, Eds. M.H. Bortner and T. Baurer, DNA 1948H (1972).*

Code S - Courtesy of Santa Barbara Research Center.

Code T - From: The Trapped Radiation Handbook, Eds. J.B. Cladis, G.T. Davidson, and L.L. Newkirk, DNA 2542H (1971).*

The Defense Nuclear Agency wishes to express its appreciation to the above-mentioned individuals and organizations, as well as to all contributors to DNA's "Reaction Rate Handbook" (DNA 1948H) and "Trapped Radiation Handbook" (DNA 2542H), for their assistance and cooperation in the creation of this Manual.

Suggestions for its improvement or revision, or other comments, should be addressed directly to the DNA Project Officer as follows:

Defense Nuclear Agency
Washington, D.C. 20305
Attn: Dr. Charles A. Blank, RAAE

It is anticipated that changes of this nature will be in order from time to time as a means of keeping the contents up-to-date; these will be distributed as the need warrants.

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*The number following these source code letters used in this Pocket Manual refers to the section or chapter of the source from which the information was derived.

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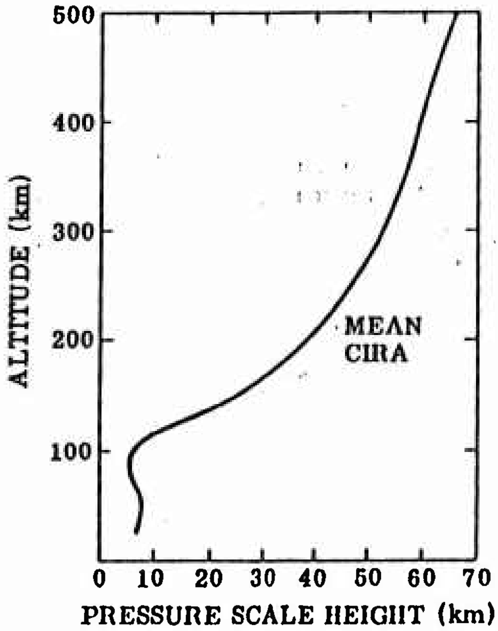
A



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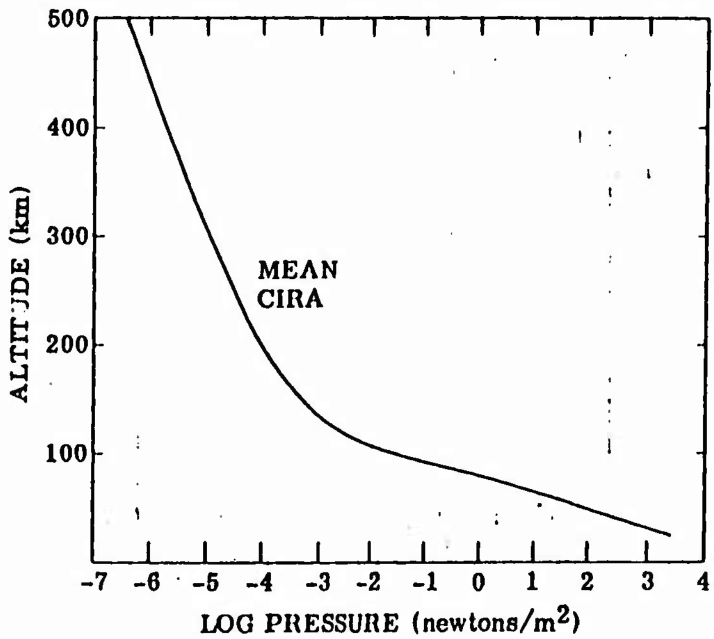

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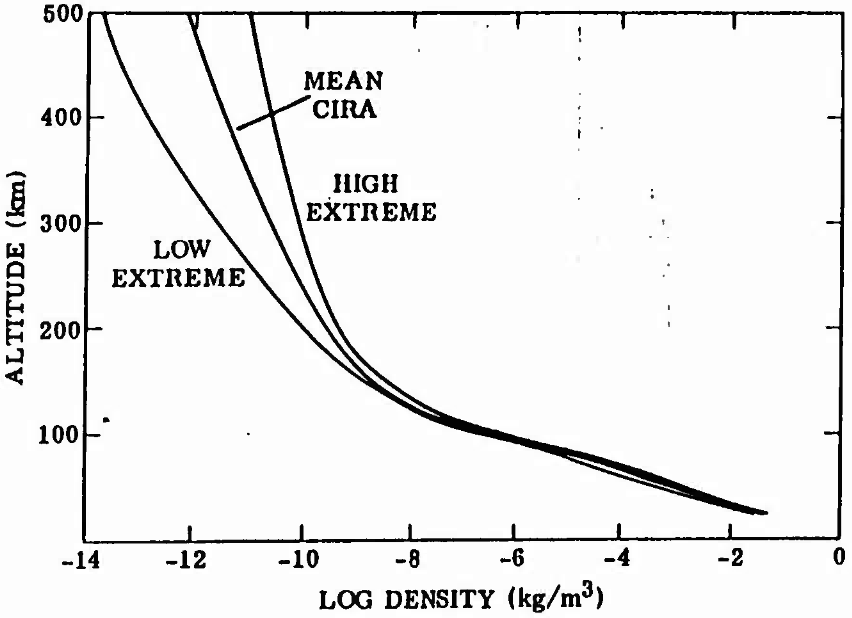

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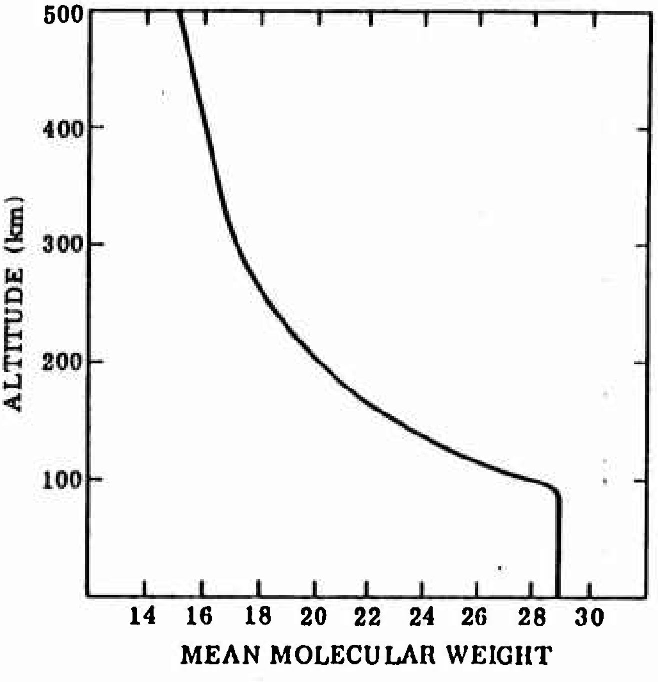

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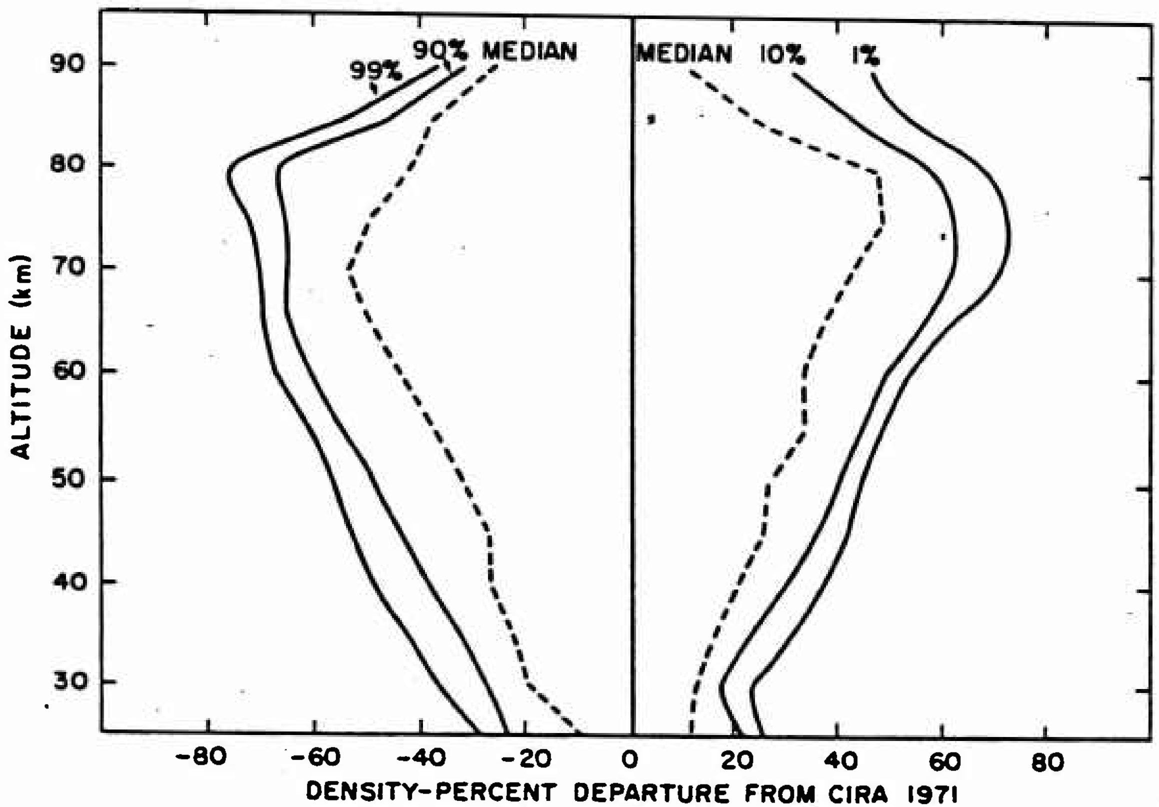

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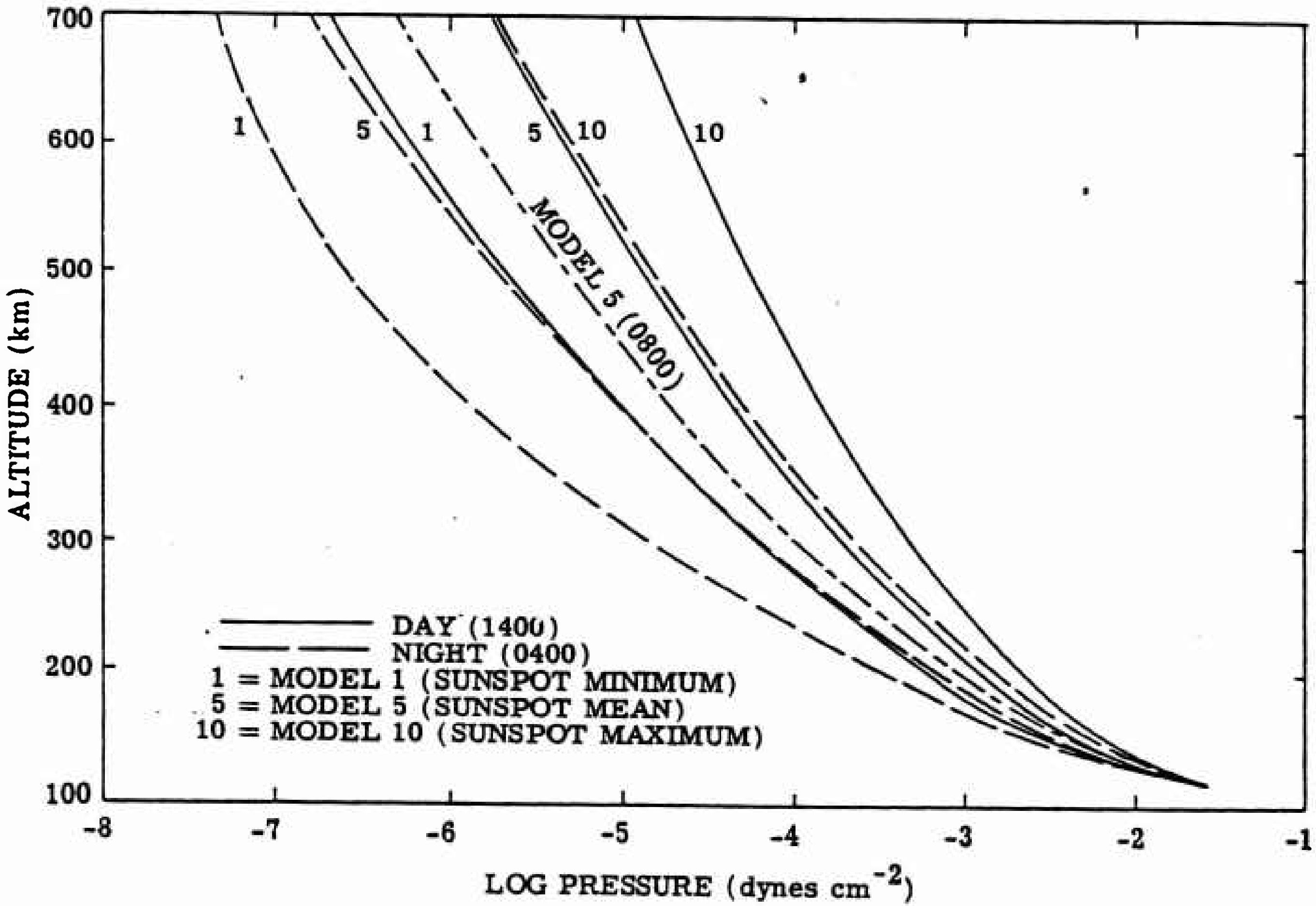

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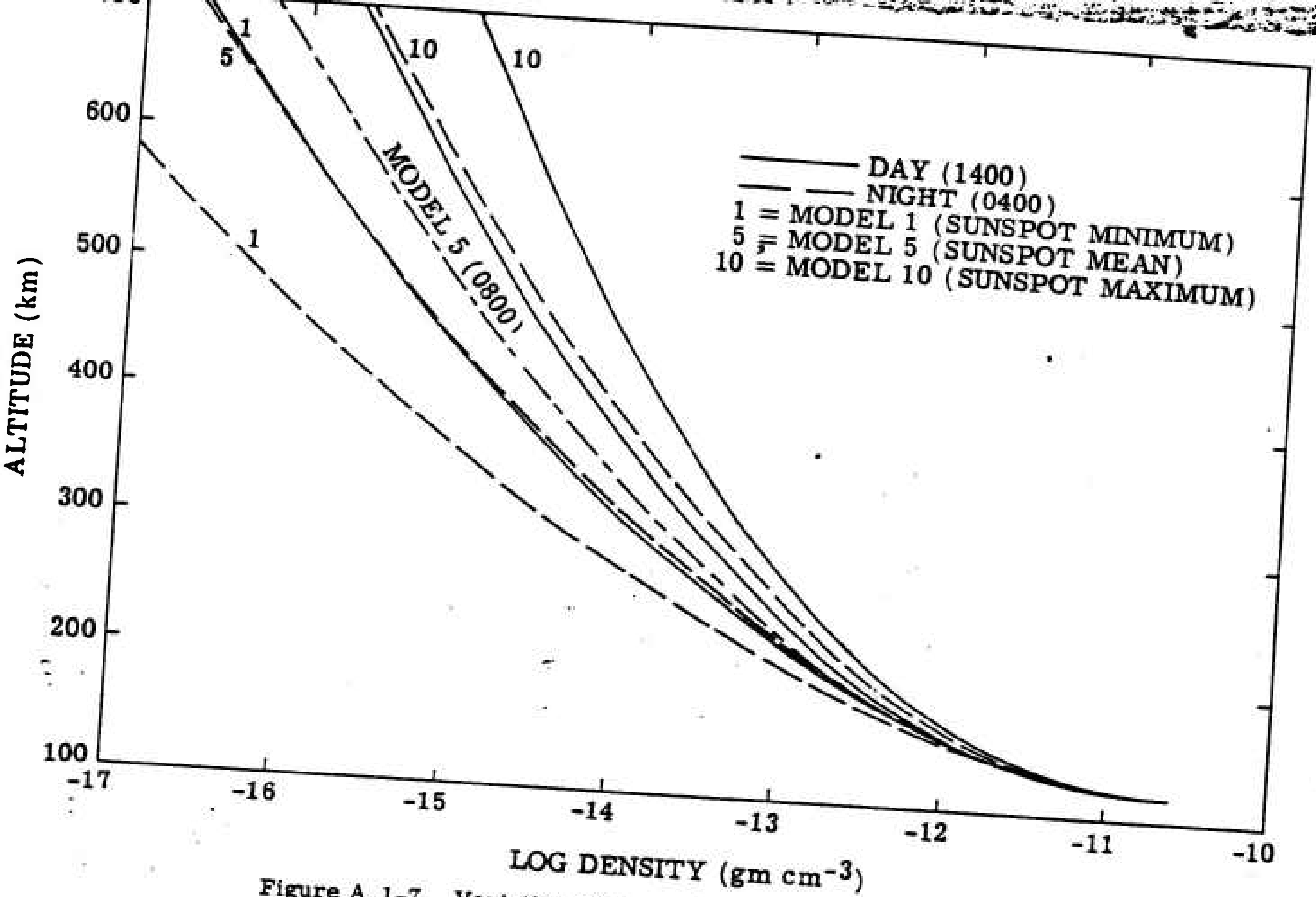

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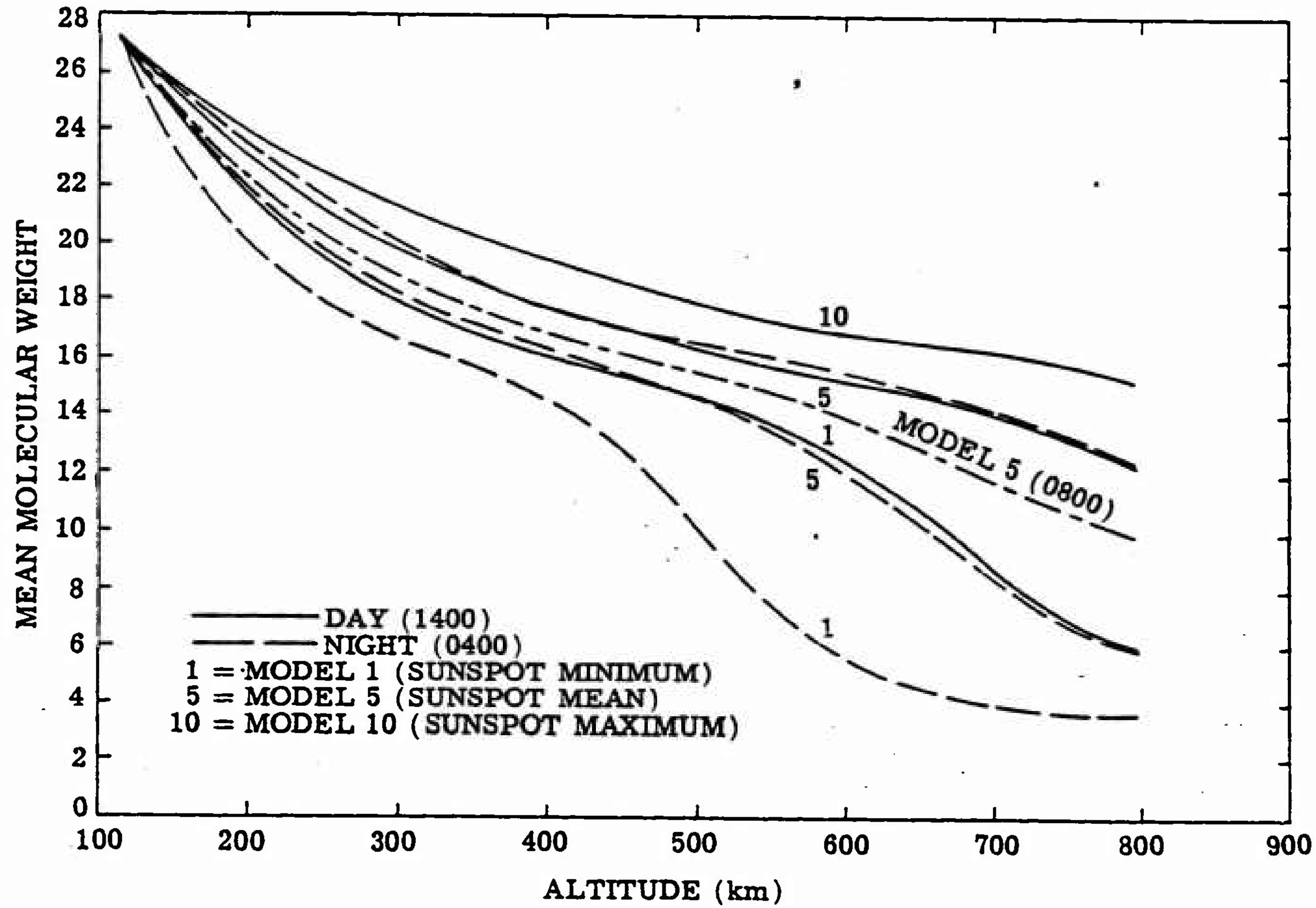

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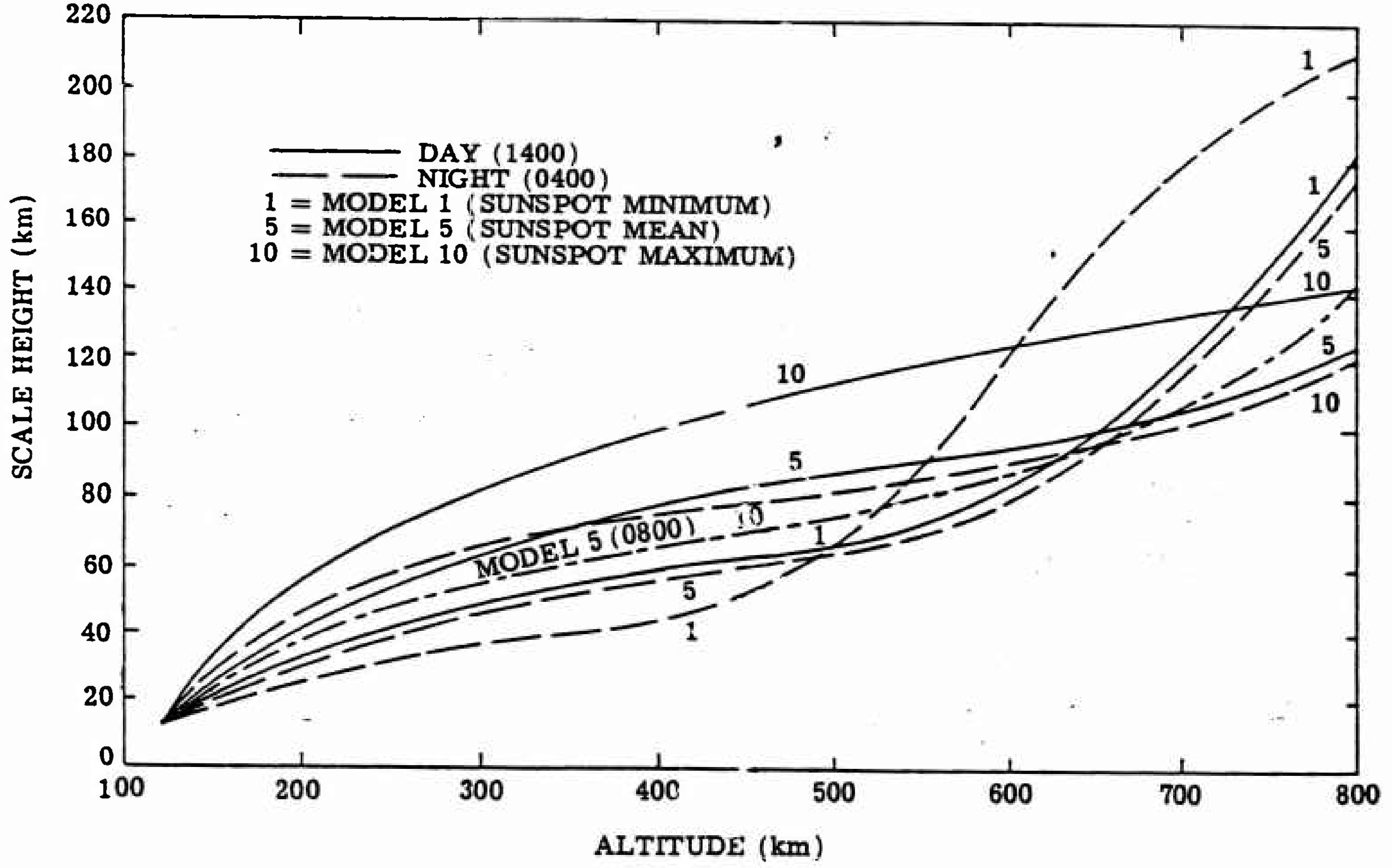

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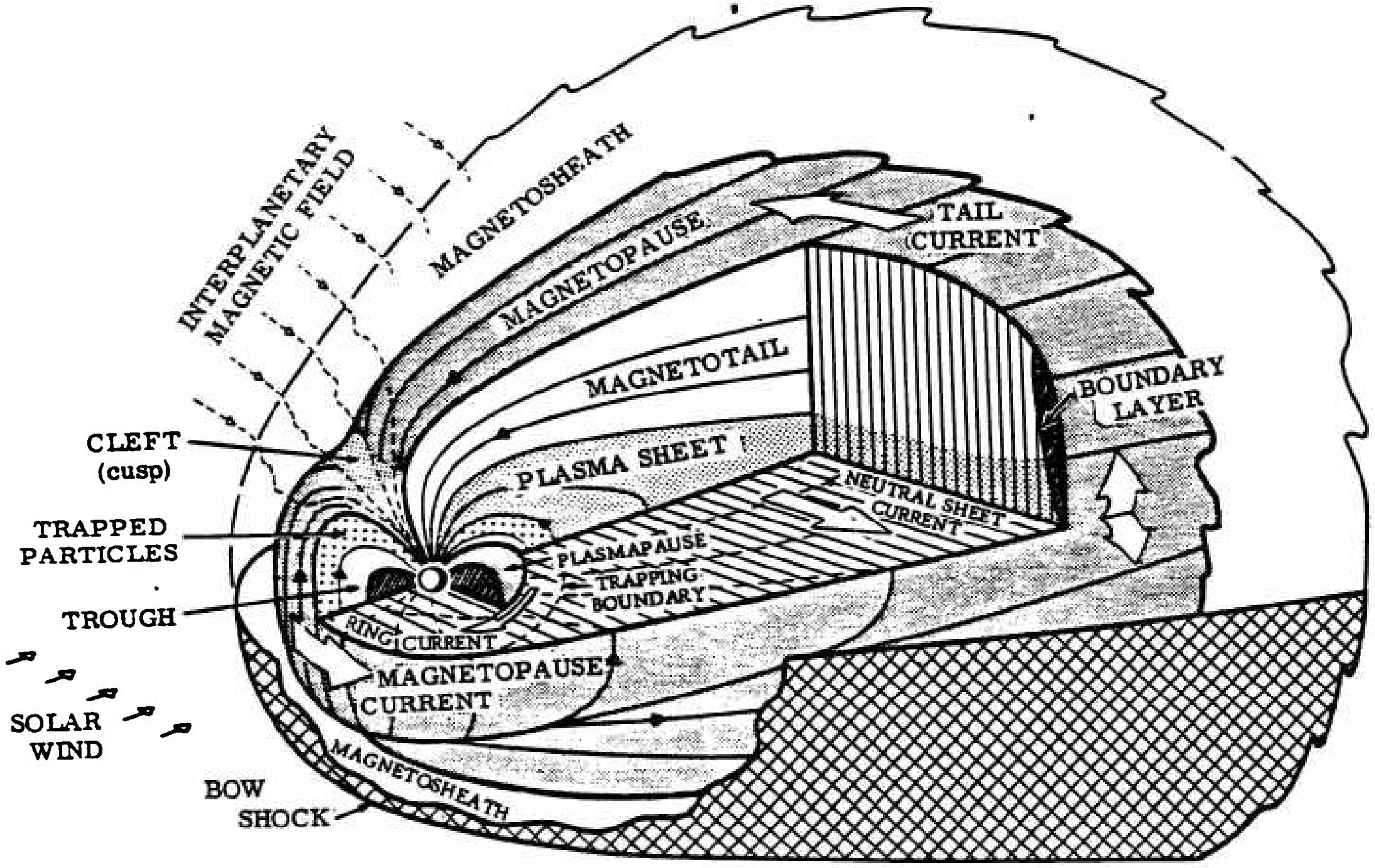

... (Source: L. after Heikkila)

Table A.1-1. Mean Reference Atmosphere structure parameters, 25 to 120 km. (Source: R-2, Table 1)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	NUMBER DENSITY /M3	PRESSURE SCALE HT KM	G M/SEC2
25	221.7	3.899E-02	-1.409	2.483E+03	3.395	8.111E+23	6.55	9.716
26	223.4	3.327E-02	-1.478	2.133E+03	3.329	6.916E+23	6.60	9.714
27	225.1	2.838E-02	-1.547	1.832E+03	3.263	5.902E+23	6.65	9.710
28	226.9	2.427E-02	-1.615	1.578E+03	3.198	5.042E+23	6.71	9.707
29	228.7	2.075E-02	-1.683	1.361E+03	3.134	4.311E+23	6.77	9.704
30	230.7	1.774E-02	-1.751	1.175E+03	3.070	3.690E+23	6.83	9.701
31	232.6	1.521E-02	-1.818	1.016E+03	3.007	3.162E+23	6.89	9.698
32	234.6	1.306E-02	-1.884	8.790E+02	2.944	2.713E+23	6.95	9.695
33	236.8	1.119E-02	-1.951	7.621E+02	2.882	2.329E+23	7.01	9.692
34	239.1	9.638E-03	-2.016	6.607E+02	2.820	2.002E+23	7.08	9.689
35	241.5	8.279E-03	-2.082	5.741E+02	2.759	1.722E+23	7.16	9.686
36	244.4	7.129E-03	-2.147	5.000E+02	2.699	1.481E+23	7.25	9.683
37	247.2	6.138E-03	-2.212	4.355E+02	2.639	1.277E+23	7.33	9.680
38	250.0	5.297E-03	-2.276	3.802E+02	2.580	1.102E+23	7.42	9.677
39	252.7	4.581E-03	-2.339	3.327E+02	2.522	9.536E+22	7.50	9.674
40	255.3	3.972E-03	-2.401	2.911E+02	2.464	8.265E+22	7.58	9.671
41	258.5	3.443E-03	-2.463	2.553E+02	2.407	7.160E+22	7.68	9.668
42	261.3	2.992E-03	-2.524	2.244E+02	2.351	6.222E+22	7.76	9.665
43	263.8	2.606E-03	-2.584	1.972E+02	2.295	5.422E+22	7.84	9.662
44	266.0	2.280E-03	-2.642	1.738E+02	2.240	4.737E+22	7.90	9.659
45	267.7	1.995E-03	-2.700	1.535E+02	2.186	4.148E+22	7.96	9.656
46	269.4	1.750E-03	-2.757	1.352E+02	2.131	3.637E+22	8.01	9.653
47	270.7	1.538E-03	-2.813	1.194E+02	2.077	3.197E+22	8.05	9.650
48	271.4	1.355E-03	-2.868	1.054E+02	2.023	2.816E+22	8.08	9.647
49	271.7	1.194E-03	-2.923	9.333E+01	1.970	2.485E+22	8.09	9.644
50	271.6	1.057E-03	-2.976	8.241E+01	1.916	2.198E+22	8.09	9.641
51	270.6	9.376E-04	-3.028	7.278E+01	1.862	1.949E+22	8.06	9.638
52	269.4	8.318E-04	-3.080	6.427E+01	1.808	1.729E+22	8.03	9.635
53	267.8	7.379E-04	-3.132	5.675E+01	1.754	1.534E+22	7.98	9.632
54	266.0	6.546E-04	-3.184	5.000E+01	1.699	1.362E+22	7.93	9.629
55	263.9	5.821E-04	-3.235	4.406E+01	1.644	1.210E+22	7.87	9.626
56	261.2	5.176E-04	-3.286	3.882E+01	1.589	1.076E+22	7.79	9.623
57	258.3	4.603E-04	-3.337	3.412E+01	1.533	9.563E+21	7.71	9.620
58	255.4	4.083E-04	-3.389	2.992E+01	1.476	8.489E+21	7.62	9.617
59	252.4	3.622E-04	-3.441	2.624E+01	1.419	7.528E+21	7.54	9.614
60	249.3	3.206E-04	-3.494	2.296E+01	1.361	6.669E+21	7.45	9.611
61	246.0	2.838E-04	-3.547	2.004E+01	1.302	5.904E+21	7.35	9.608
62	242.7	2.512E-04	-3.600	1.750E+01	1.243	5.219E+21	7.25	9.605
63	239.4	2.213E-04	-3.655	1.521E+01	1.182	4.606E+21	7.16	9.602
64	236.1	1.950E-04	-3.710	1.321E+01	1.121	4.057E+21	7.06	9.599
65	232.7	1.718E-04	-3.765	1.146E+01	1.059	3.568E+21	6.96	9.596
66	229.0	1.510E-04	-3.821	9.908E+00	.996	3.137E+21	6.85	9.593
67	225.5	1.321E-04	-3.879	8.570E+00	.933	2.751E+21	6.75	9.590
68	222.2	1.156E-04	-3.937	7.379E+00	.868	2.404E+21	6.65	9.587
69	219.1	1.007E-04	-3.997	6.339E+00	.802	2.096E+21	6.56	9.584
70	216.2	8.770E-05	-4.057	5.445E+00	.736	1.822E+21	6.48	9.581
71	213.7	7.586E-05	-4.120	4.656E+00	.668	1.578E+21	6.41	9.578
72	211.3	6.561E-05	-4.183	3.981E+00	.600	1.364E+21	6.34	9.575

Table A.1-1. (Continued)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	NUMBER DENSITY /M3	PRESSURE SCALE HT KM	G M/SEC2
73	209.1	5.662E-05	-4.247	3.396E+00	.531	1.177E+21	6.27	9.572
74	207.0	4.875E-05	-4.312	2.891E+00	.461	1.013E+21	6.21	9.569
75	205.0	4.178E-05	-4.379	2.460E+00	.391	8.696E+20	6.15	9.566
76	203.0	3.581E-05	-4.446	2.089E+00	.320	7.455E+20	6.09	9.563
77	201.0	3.069E-05	-4.513	1.770E+00	.248	6.381E+20	6.04	9.560
78	199.0	2.624E-05	-4.581	1.496E+00	.175	5.453E+20	5.98	9.557
79	197.0	2.239E-05	-4.650	1.265E+00	.102	4.653E+20	5.92	9.554
80	195.0	1.905E-05	-4.720	1.067E+00	.028	3.964E+20	5.86	9.551
81	193.0	1.622E-05	-4.790	8.974E-01	-.047	3.371E+20	5.80	9.548
82	191.0	1.377E-05	-4.861	7.551E-01	-.122	2.864E+20	5.75	9.545
83	189.0	1.167E-05	-4.933	6.324E-01	-.199	2.428E+20	5.69	9.542
84	187.1	9.863E-06	-5.006	5.297E-01	-.276	2.055E+20	5.63	9.539
85	185.1	8.337E-06	-5.079	4.426E-01	-.354	1.736E+20	5.57	9.536
86	184.8	6.982E-06	-5.156	3.698E-01	-.432	1.453E+20	5.57	9.533
87	184.5	5.834E-06	-5.234	3.090E-01	-.510	1.215E+20	5.56	9.530
88	184.2	4.875E-06	-5.312	2.576E-01	-.589	1.015E+20	5.55	9.527
89	184.0	4.074E-06	-5.390	2.148E-01	-.668	8.482E+19	5.55	9.524
90	183.8	3.396E-06	-5.469	1.795E-01	-.746	7.087E+19	5.54	9.521
91	184.6	2.825E-06	-5.549	1.496E-01	-.825	5.890E+19	5.57	9.518
92	185.4	2.350E-06	-5.629	1.250E-01	-.903	4.901E+19	5.59	9.515
93	186.7	1.950E-06	-5.710	1.045E-01	-.981	4.072E+19	5.64	9.512
94	188.0	1.622E-06	-5.790	8.750E-02	-1.058	3.386E+19	5.68	9.509
95	190.3	1.343E-06	-5.872	7.345E-02	-1.134	2.808E+19	5.75	9.506
96	192.0	1.119E-06	-5.951	6.166E-02	-1.210	2.344E+19	5.80	9.503
97	194.5	9.311E-07	-6.031	5.200E-02	-1.284	1.952E+19	5.88	9.500
98	197.1	7.745E-07	-6.111	4.385E-02	-1.358	1.630E+19	5.96	9.498
99	200.3	6.442E-07	-6.191	3.707E-02	-1.431	1.362E+19	6.06	9.495
100	203.5	5.297E-07	-6.276	3.090E-02	-1.510	1.125E+19	6.16	9.492
101	207.3	4.355E-07	-6.361	2.588E-02	-1.587	9.305E+18	6.27	9.489
102	211.6	3.648E-07	-6.438	2.218E-02	-1.654	7.856E+18	6.40	9.486
103	216.7	3.062E-07	-6.514	1.905E-02	-1.720	6.634E+18	6.56	9.483
104	221.7	2.582E-07	-6.588	1.644E-02	-1.784	5.628E+18	6.71	9.480
105	228.0	2.173E-07	-6.663	1.422E-02	-1.847	4.768E+18	6.91	9.477
106	234.2	1.841E-07	-6.735	1.236E-02	-1.908	4.060E+18	7.10	9.474
107	241.1	1.560E-07	-6.807	1.079E-02	-1.967	3.463E+18	7.31	9.471
108	248.6	1.327E-07	-6.877	9.462E-03	-2.024	2.961E+18	7.54	9.468
109	256.8	1.130E-07	-6.947	8.337E-03	-2.079	2.538E+18	7.79	9.465
110	265.5	9.661E-08	-7.015	7.362E-03	-2.133	2.182E+18	8.06	9.462
111	274.9	8.279E-08	-7.082	6.546E-03	-2.184	1.881E+18	8.34	9.459
112	284.8	7.129E-08	-7.147	5.834E-03	-2.234	1.627E+18	8.65	9.456
113	295.1	6.166E-08	-7.210	5.224E-03	-2.282	1.413E+18	8.96	9.454
114	305.9	5.346E-08	-7.272	4.688E-03	-2.329	1.231E+18	9.29	9.451
115	317.1	4.645E-08	-7.333	4.236E-03	-2.373	1.076E+18	9.64	9.448
116	329.2	4.055E-08	-7.392	3.837E-03	-2.416	9.433E+17	10.01	9.445
117	341.6	3.548E-08	-7.450	3.483E-03	-2.458	8.298E+17	10.39	9.442
118	354.3	3.126E-08	-7.505	3.177E-03	-2.498	7.327E+17	10.78	9.439
119	366.9	2.761E-08	-7.559	2.904E-03	-2.537	6.499E+17	11.16	9.436
120	380.6	2.438E-08	-7.613	2.667E-03	-2.574	5.772E+17	11.58	9.433

Table A.1-2. Mean Reference Atmosphere structure parameters, 120 to 500 km. (Source: R-2, Table 3)

EIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	DENSITY SCALE HT KM	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	PRESSURE SCALE HT KM	G M/SEC2
120	380.6	2.440E-08	-7.613	8.17	2.666E-03	-2.574	11.58	9.433
121	394.5	2.162E-08	-7.665	8.42	2.449E-03	-2.611	12.01	9.430
122	408.6	1.924E-08	-7.716	8.67	2.257E-03	-2.647	12.44	9.427
123	423.0	1.717E-08	-7.765	8.94	2.085E-03	-2.681	12.89	9.424
124	437.6	1.538E-08	-7.813	9.21	1.932E-03	-2.714	13.33	9.421
125	452.3	1.382E-08	-7.859	9.51	1.795E-03	-2.746	13.79	9.418
126	467.1	1.246E-08	-7.904	9.80	1.671E-03	-2.777	14.24	9.416
127	482.0	1.127E-08	-7.948	10.10	1.560E-03	-2.807	14.70	9.413
128	497.0	1.022E-08	-7.990	10.41	1.459E-03	-2.836	15.16	9.410
129	511.9	9.300E-09	-8.032	10.73	1.367E-03	-2.864	15.62	9.407
130	526.9	8.484E-09	-8.071	11.05	1.283E-03	-2.892	16.08	9.404
131	541.8	7.759E-09	-8.110	11.37	1.207E-03	-2.918	16.55	9.401
132	556.7	7.115E-09	-8.148	11.70	1.137E-03	-2.944	17.01	9.398
133	571.5	6.540E-09	-8.184	12.03	1.073E-03	-2.969	17.46	9.395
134	586.3	6.025E-09	-8.220	12.36	1.014E-03	-2.994	17.92	9.392
135	600.9	5.563E-09	-8.255	12.70	9.597E-04	-3.018	18.37	9.389
136	615.5	5.147E-09	-8.288	13.04	9.094E-04	-3.041	18.83	9.387
137	629.9	4.772E-09	-8.321	13.39	8.629E-04	-3.064	19.27	9.384
138	644.2	4.432E-09	-8.353	13.73	8.198E-04	-3.086	19.72	9.381
139	658.4	4.125E-09	-8.385	14.08	7.797E-04	-3.108	20.16	9.378
140	672.4	3.845E-09	-8.415	14.44	7.423E-04	-3.129	20.59	9.375
141	686.2	3.591E-09	-8.445	14.79	7.075E-04	-3.150	21.02	9.372
142	699.9	3.359E-09	-8.474	15.14	6.749E-04	-3.171	21.45	9.369
143	713.4	3.147E-09	-8.502	15.50	6.445E-04	-3.191	21.87	9.366
144	726.7	2.952E-09	-8.530	15.85	6.159E-04	-3.210	22.28	9.363
145	739.8	2.774E-09	-8.557	16.21	5.891E-04	-3.230	22.69	9.360
146	752.8	2.609E-09	-8.583	16.56	5.640E-04	-3.249	23.10	9.358
147	765.6	2.458E-09	-8.609	16.92	5.403E-04	-3.267	23.50	9.355
148	778.1	2.318E-09	-8.635	17.27	5.179E-04	-3.286	23.89	9.352
149	790.5	2.189E-09	-8.660	17.63	4.969E-04	-3.304	24.28	9.349
150	802.7	2.070E-09	-8.684	17.98	4.770E-04	-3.321	24.66	9.346
151	814.7	1.959E-09	-8.708	18.32	4.582E-04	-3.339	25.04	9.343
152	826.6	1.856E-09	-8.731	18.67	4.404E-04	-3.356	25.41	9.340
153	838.2	1.760E-09	-8.755	19.02	4.235E-04	-3.373	25.77	9.337
54	849.7	1.670E-09	-8.777	19.36	4.075E-04	-3.390	26.13	9.335
55	861.0	1.587E-09	-8.799	19.70	3.923E-04	-3.406	26.49	9.332
56	872.1	1.509E-09	-8.821	20.04	3.778E-04	-3.423	26.84	9.329
57	883.0	1.436E-09	-8.843	20.37	3.641E-04	-3.439	27.18	9.326
58	893.8	1.368E-09	-8.864	20.71	3.510E-04	-3.455	27.52	9.323
59	904.4	1.304E-09	-8.885	21.04	3.386E-04	-3.470	27.86	9.320
60	914.8	1.244E-09	-8.905	21.37	3.267E-04	-3.486	28.19	9.317

Table A.1-2. (Continued)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	DENSITY SCALE HT KM	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	PRESSURE SCALE HT KM	G M/SEC2
161	925.1	1.188E-09	-8.925	21.69	3.154E-04	-3.501	28.51	9.314
162	935.2	1.134E-09	-8.945	22.01	3.046E-04	-3.516	28.83	9.312
163	945.2	1.084E-09	-8.965	22.33	2.943E-04	-3.531	29.15	9.309
164	955.0	1.037E-09	-8.984	22.65	2.844E-04	-3.546	29.46	9.306
165	964.7	9.927E-10	-9.003	22.96	2.749E-04	-3.561	29.77	9.303
166	974.2	9.507E-10	-9.022	23.28	2.659E-04	-3.575	30.07	9.300
167	983.6	9.110E-10	-9.040	23.58	2.573E-04	-3.590	30.37	9.297
168	992.9	8.734E-10	-9.059	23.88	2.490E-04	-3.604	30.67	9.294
169	1002.1	8.378E-10	-9.077	24.17	2.410E-04	-3.618	30.96	9.292
170	1011.1	8.040E-10	-9.095	24.48	2.334E-04	-3.632	31.25	9.289
171	1020.0	7.720E-10	-9.112	24.78	2.261E-04	-3.646	31.53	9.286
172	1028.7	7.417E-10	-9.130	25.06	2.191E-04	-3.659	31.82	9.283
173	1037.4	7.128E-10	-9.147	25.35	2.123E-04	-3.673	32.09	9.280
174	1045.9	6.854E-10	-9.164	25.64	2.058E-04	-3.687	32.37	9.277
175	1054.4	6.593E-10	-9.181	25.92	1.996E-04	-3.700	32.64	9.274
176	1062.7	6.345E-10	-9.198	26.20	1.936E-04	-3.713	32.91	9.272
177	1070.9	6.109E-10	-9.214	26.47	1.878E-04	-3.726	33.17	9.269
178	1079.0	5.883E-10	-9.230	26.75	1.823E-04	-3.739	33.43	9.266
179	1087.1	5.669E-10	-9.247	27.02	1.769E-04	-3.752	33.69	9.263
180	1095.0	5.464E-10	-9.263	27.29	1.718E-04	-3.765	33.95	9.260
181	1102.8	5.268E-10	-9.278	27.56	1.668E-04	-3.778	34.20	9.257
182	1110.5	5.081E-10	-9.294	27.82	1.620E-04	-3.790	34.45	9.255
183	1118.2	4.903E-10	-9.310	28.08	1.574E-04	-3.803	34.70	9.252
184	1125.7	4.732E-10	-9.325	28.34	1.529E-04	-3.816	34.94	9.249
185	1133.2	4.568E-10	-9.340	28.60	1.486E-04	-3.828	35.19	9.246
186	1140.6	4.412E-10	-9.355	28.86	1.445E-04	-3.840	35.43	9.243
187	1147.9	4.262E-10	-9.370	29.11	1.405E-04	-3.852	35.66	9.240
188	1155.1	4.119E-10	-9.385	29.35	1.366E-04	-3.865	35.90	9.238
189	1162.2	3.982E-10	-9.400	29.60	1.329E-04	-3.877	36.13	9.235
190	1169.3	3.850E-10	-9.415	29.85	1.292E-04	-3.889	36.36	9.232
191	1176.2	3.724E-10	-9.429	30.09	1.257E-04	-3.901	36.59	9.229
192	1183.1	3.602E-10	-9.443	30.34	1.224E-04	-3.912	36.82	9.226
193	1190.0	3.486E-10	-9.458	30.58	1.191E-04	-3.924	37.04	9.223
194	1196.7	3.374E-10	-9.472	30.82	1.159E-04	-3.936	37.26	9.221
195	1203.4	3.267E-10	-9.486	31.05	1.129E-04	-3.947	37.48	9.218
196	1210.0	3.164E-10	-9.500	31.28	1.099E-04	-3.959	37.70	9.215
197	1216.6	3.065E-10	-9.514	31.51	1.070E-04	-3.970	37.91	9.212
198	1223.1	2.969E-10	-9.527	31.74	1.043E-04	-3.982	38.13	9.209
199	1229.5	2.878E-10	-9.541	31.98	1.016E-04	-3.993	38.34	9.207
200	1235.8	2.789E-10	-9.555	32.21	9.896E-05	-4.005	38.55	9.204

Table A.1-2. (Continued)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	DENSITY SCALE HT KM	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	PRESSURE SCALE HT KM	G M/SEC2
202	1248.3	2.622E-10	-9.581	32.66	9.399E-05	-4.027	38.96	9.198
204	1260.6	2.468E-10	-9.608	33.10	8.931E-05	-4.049	39.37	9.192
206	1272.6	2.324E-10	-9.634	33.54	8.491E-05	-4.071	39.77	9.187
208	1284.4	2.190E-10	-9.660	33.97	8.076E-05	-4.093	40.16	9.181
210	1295.9	2.066E-10	-9.685	34.40	7.686E-05	-4.114	40.55	9.176
212	1307.2	1.950E-10	-9.710	34.82	7.317E-05	-4.136	40.93	9.170
214	1318.3	1.842E-10	-9.735	35.24	6.970E-05	-4.157	41.30	9.164
216	1329.2	1.741E-10	-9.759	35.65	6.642E-05	-4.178	41.66	9.159
218	1339.9	1.646E-10	-9.784	36.06	6.332E-05	-4.198	42.03	9.153
220	1350.3	1.558E-10	-9.808	36.45	6.039E-05	-4.219	42.38	9.148
222	1360.6	1.475E-10	-9.831	36.85	5.762E-05	-4.239	42.73	9.142
224	1370.6	1.398E-10	-9.855	37.24	5.499E-05	-4.260	43.07	9.137
226	1380.5	1.325E-10	-9.878	37.63	5.251E-05	-4.280	43.41	9.131
228	1390.2	1.257E-10	-9.901	38.01	5.015E-05	-4.300	43.74	9.125
230	1399.6	1.192E-10	-9.924	38.39	4.792E-05	-4.320	44.06	9.120
232	1408.9	1.132E-10	-9.946	38.77	4.580E-05	-4.339	44.38	9.114
234	1418.1	1.076E-10	-9.968	39.13	4.379E-05	-4.359	44.70	9.109
236	1427.0	1.022E-10	-9.990	39.49	4.188E-05	-4.378	45.00	9.103
238	1435.8	9.720E-11	-10.012	39.85	4.006E-05	-4.397	45.31	9.098
240	1444.4	9.246E-11	-10.034	40.21	3.834E-05	-4.416	45.61	9.092
242	1452.8	8.799E-11	-10.056	40.56	3.670E-05	-4.435	45.90	9.087
244	1461.0	8.378E-11	-10.077	40.91	3.514E-05	-4.454	46.19	9.081
246	1469.1	7.979E-11	-10.098	41.25	3.366E-05	-4.473	46.47	9.076
248	1477.1	7.603E-11	-10.119	41.59	3.224E-05	-4.492	46.75	9.070
250	1484.9	7.248E-11	-10.140	41.92	3.090E-05	-4.510	47.03	9.065
252	1492.5	6.911E-11	-10.160	42.25	2.961E-05	-4.529	47.30	9.059
254	1499.9	6.593E-11	-10.181	42.58	2.839E-05	-4.547	47.56	9.054
256	1507.3	6.292E-11	-10.201	42.90	2.723E-05	-4.565	47.83	9.048
258	1514.4	6.006E-11	-10.221	43.21	2.611E-05	-4.583	48.08	9.043
260	1521.5	5.735E-11	-10.241	43.52	2.505E-05	-4.601	48.33	9.037
262	1528.4	5.478E-11	-10.261	43.83	2.404E-05	-4.619	48.58	9.032
264	1535.1	5.235E-11	-10.281	44.13	2.307E-05	-4.637	48.83	9.026
266	1541.7	5.004E-11	-10.301	44.44	2.215E-05	-4.655	49.07	9.021
268	1548.2	4.784E-11	-10.320	44.74	2.127E-05	-4.672	49.30	9.015
270	1554.6	4.576E-11	-10.340	45.03	2.042E-05	-4.690	49.54	9.010
272	1560.8	4.378E-11	-10.359	45.32	1.962E-05	-4.707	49.76	9.004
274	1566.9	4.189E-11	-10.378	45.60	1.885E-05	-4.725	49.99	8.999
276	1572.9	4.010E-11	-10.397	45.88	1.811E-05	-4.742	50.21	8.993
278	1578.7	3.839E-11	-10.416	46.16	1.740E-05	-4.759	50.43	8.988
280	1584.5	3.677E-11	-10.434	46.43	1.673E-05	-4.777	50.64	8.983
282	1590.1	3.522E-11	-10.453	46.70	1.608E-05	-4.794	50.85	8.977
284	1595.6	3.375E-11	-10.472	46.96	1.546E-05	-4.811	51.06	8.972
286	1601.0	3.235E-11	-10.490	47.22	1.487E-05	-4.828	51.26	8.966
288	1606.3	3.101E-11	-10.508	47.48	1.430E-05	-4.845	51.46	8.961
290	1611.5	2.974E-11	-10.527	47.73	1.376E-05	-4.861	51.66	8.955
292	1616.6	2.852E-11	-10.545	47.98	1.324E-05	-4.878	51.86	8.950
294	1621.6	2.736E-11	-10.563	48.23	1.274E-05	-4.895	52.05	8.945
296	1626.5	2.625E-11	-10.581	48.47	1.226E-05	-4.912	52.24	8.939
298	1631.2	2.519E-11	-10.599	48.71	1.180E-05	-4.928	52.42	8.934
300	1636.0	2.418E-11	-10.617	48.95	1.136E-05	-4.945	52.60	8.928

Table A.1-2. (Continued)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	DENSITY SCALE HT KM	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	PRESSURE SCALE HT KM	G M/SEC2
302	1640.6	2.321E-11	-10.634	49.19	1.093E-05	-4.961	52.78	8.923
304	1645.1	2.229E-11	-10.652	49.42	1.053E-05	-4.978	52.96	8.918
306	1649.5	2.141E-11	-10.669	49.64	1.014E-05	-4.994	53.14	8.912
308	1653.8	2.056E-11	-10.687	49.86	9.764E-06	-5.010	53.31	8.907
310	1658.1	1.976E-11	-10.704	50.07	9.405E-06	-5.027	53.48	8.902
312	1662.3	1.899E-11	-10.722	50.28	9.061E-06	-5.043	53.64	8.896
314	1666.4	1.825E-11	-10.739	50.50	8.730E-06	-5.059	53.81	8.891
316	1670.4	1.754E-11	-10.756	50.70	8.412E-06	-5.075	53.97	8.886
318	1674.3	1.686E-11	-10.773	50.91	8.106E-06	-5.091	54.13	8.880
320	1678.2	1.621E-11	-10.790	51.12	7.812E-06	-5.107	54.29	8.875
322	1682.0	1.559E-11	-10.807	51.32	7.530E-06	-5.123	54.44	8.870
324	1685.7	1.500E-11	-10.824	51.51	7.259E-06	-5.139	54.60	8.864
326	1689.4	1.443E-11	-10.841	51.71	6.998E-06	-5.155	54.75	8.859
328	1693.0	1.388E-11	-10.858	51.90	6.747E-06	-5.171	54.90	8.854
330	1696.5	1.336E-11	-10.874	52.09	6.507E-06	-5.187	55.05	8.848
332	1700.0	1.286E-11	-10.891	52.28	6.275E-06	-5.202	55.19	8.843
334	1703.4	1.237E-11	-10.907	52.46	6.052E-06	-5.218	55.34	8.838
336	1706.8	1.191E-11	-10.924	52.64	5.837E-06	-5.234	55.48	8.832
338	1710.1	1.147E-11	-10.940	52.81	5.631E-06	-5.249	55.62	8.827
340	1713.4	1.104E-11	-10.957	52.98	5.432E-06	-5.265	55.76	8.822
342	1716.6	1.063E-11	-10.973	53.16	5.241E-06	-5.281	55.90	8.816
344	1719.7	1.024E-11	-10.990	53.32	5.057E-06	-5.296	56.03	8.811
346	1722.8	9.866E-12	-11.006	53.49	4.880E-06	-5.312	56.17	8.806
348	1725.8	9.505E-12	-11.022	53.65	4.709E-06	-5.327	56.30	8.801
350	1728.8	9.158E-12	-11.038	53.81	4.545E-06	-5.342	56.43	8.795
352	1731.8	8.824E-12	-11.054	53.97	4.387E-06	-5.358	56.56	8.790
354	1734.7	8.503E-12	-11.070	54.13	4.235E-06	-5.373	56.69	8.785
356	1737.6	8.195E-12	-11.086	54.29	4.088E-06	-5.388	56.82	8.780
358	1740.4	7.899E-12	-11.102	54.44	3.947E-06	-5.404	56.95	8.774
360	1743.2	7.615E-12	-11.118	54.59	3.811E-06	-5.419	57.07	8.769
362	1746.0	7.341E-12	-11.134	54.74	3.680E-06	-5.434	57.20	8.764
364	1748.7	7.078E-12	-11.150	54.89	3.554E-06	-5.449	57.32	8.759
366	1751.4	6.825E-12	-11.166	55.03	3.432E-06	-5.464	57.44	8.753
368	1754.1	6.582E-12	-11.182	55.17	3.315E-06	-5.480	57.57	8.748
370	1756.7	6.348E-12	-11.197	55.31	3.202E-06	-5.495	57.69	8.743
372	1759.3	6.123E-12	-11.213	55.45	3.093E-06	-5.510	57.81	8.738
374	1761.9	5.906E-12	-11.229	55.59	2.988E-06	-5.525	57.93	8.732
376	1764.5	5.698E-12	-11.244	55.72	2.886E-06	-5.540	58.05	8.727
378	1767.0	5.497E-12	-11.260	55.85	2.789E-06	-5.555	58.16	8.722
380	1769.5	5.304E-12	-11.275	55.98	2.694E-06	-5.570	58.28	8.717
382	1772.0	5.118E-12	-11.291	56.11	2.604E-06	-5.584	58.40	8.712
384	1774.5	4.939E-12	-11.306	56.24	2.516E-06	-5.599	58.51	8.706
386	1776.9	4.767E-12	-11.322	56.35	2.432E-06	-5.614	58.63	8.701
388	1779.4	4.600E-12	-11.337	56.48	2.350E-06	-5.629	58.74	8.696
390	1781.8	4.441E-12	-11.353	56.60	2.272E-06	-5.644	58.86	8.691
392	1784.2	4.287E-12	-11.368	56.72	2.196E-06	-5.658	58.97	8.686
394	1786.6	4.138E-12	-11.383	56.84	2.123E-06	-5.673	59.09	8.681
396	1788.9	3.995E-12	-11.398	56.96	2.052E-06	-5.688	59.20	8.675
398	1791.3	3.858E-12	-11.414	57.09	1.984E-06	-5.702	59.32	8.670
400	1793.7	3.725E-12	-11.429	57.20	1.918E-06	-5.717	59.43	8.665

Table A.1-2. (Continued)

HEIGHT KM	MOLEC TEMP K	DENSITY KG/M3	LOG DEN (KG/M3)	DENSITY SCALE HT KM	PRESSURE NT/M2	LOG PRESSURE (NT/M2)	PRESSURE SCALE HT KM	G M/SEC2
402	1796.0	3.597E-12	-11.444	57.32	1.855E-06	-5.732	59.54	8.660
404	1798.4	3.474E-12	-11.459	57.43	1.794E-06	-5.746	59.66	8.655
406	1800.7	3.355E-12	-11.474	57.54	1.735E-06	-5.761	59.77	8.650
408	1803.1	3.241E-12	-11.489	57.65	1.677E-06	-5.775	59.88	8.644
410	1805.4	3.130E-12	-11.504	57.75	1.622E-06	-5.790	60.00	8.639
412	1807.8	3.024E-12	-11.519	57.86	1.569E-06	-5.804	60.11	8.634
414	1810.1	2.921E-12	-11.534	57.97	1.518E-06	-5.819	60.22	8.629
416	1812.5	2.822E-12	-11.549	58.07	1.468E-06	-5.833	60.34	8.624
418	1814.8	2.727E-12	-11.564	58.18	1.421E-06	-5.848	60.45	8.619
420	1817.2	2.635E-12	-11.579	58.28	1.374E-06	-5.862	60.57	8.614
422	1819.5	2.546E-12	-11.594	58.38	1.330E-06	-5.876	60.68	8.609
424	1821.9	2.460E-12	-11.609	58.49	1.287E-06	-5.890	60.80	8.603
426	1824.3	2.377E-12	-11.624	58.59	1.245E-06	-5.905	60.91	8.598
428	1826.7	2.298E-12	-11.639	58.69	1.205E-06	-5.919	61.03	8.593
430	1829.1	2.221E-12	-11.653	58.79	1.166E-06	-5.933	61.14	8.588
432	1831.5	2.147E-12	-11.668	58.89	1.129E-06	-5.947	61.26	8.583
434	1833.9	2.075E-12	-11.683	58.98	1.092E-06	-5.962	61.38	8.578
436	1836.3	2.006E-12	-11.698	59.08	1.057E-06	-5.976	61.50	8.573
438	1838.8	1.939E-12	-11.712	59.17	1.024E-06	-5.990	61.62	8.568
440	1841.3	1.875E-12	-11.727	59.26	9.910E-07	-6.004	61.74	8.563
442	1843.8	1.813E-12	-11.742	59.36	9.595E-07	-6.018	61.86	8.558
444	1846.3	1.753E-12	-11.756	59.45	9.290E-07	-6.032	61.98	8.553
446	1848.8	1.695E-12	-11.771	59.54	8.995E-07	-6.046	62.10	8.548
448	1851.4	1.639E-12	-11.786	59.64	8.710E-07	-6.060	62.22	8.542
450	1854.0	1.585E-12	-11.800	59.73	8.435E-07	-6.074	62.35	8.537
452	1856.6	1.533E-12	-11.815	59.82	8.169E-07	-6.088	62.47	8.532
454	1859.3	1.482E-12	-11.829	59.91	7.912E-07	-6.102	62.60	8.527
456	1861.9	1.434E-12	-11.844	60.00	7.663E-07	-6.116	62.72	8.522
458	1864.6	1.387E-12	-11.858	60.09	7.423E-07	-6.129	62.85	8.517
460	1867.4	1.341E-12	-11.872	60.18	7.191E-07	-6.143	62.98	8.512
462	1870.2	1.297E-12	-11.887	60.27	6.966E-07	-6.157	63.11	8.507
464	1873.0	1.255E-12	-11.901	60.36	6.749E-07	-6.171	63.25	8.502
466	1875.8	1.214E-12	-11.916	60.45	6.539E-07	-6.184	63.38	8.497
468	1878.7	1.175E-12	-11.930	60.54	6.337E-07	-6.198	63.51	8.492
470	1881.6	1.137E-12	-11.944	60.63	6.140E-07	-6.212	63.65	8.487
472	1884.6	1.100E-12	-11.959	60.72	5.950E-07	-6.225	63.79	8.482
474	1887.6	1.064E-12	-11.973	60.81	5.767E-07	-6.239	63.93	8.477
476	1890.7	1.030E-12	-11.987	60.90	5.590E-07	-6.253	64.07	8.472
478	1893.8	9.965E-13	-12.002	60.98	5.418E-07	-6.266	64.21	8.467
480	1896.9	9.644E-13	-12.016	61.08	5.252E-07	-6.280	64.36	8.462
482	1900.1	9.333E-13	-12.030	61.16	5.092E-07	-6.293	64.50	8.457
484	1903.4	9.033E-13	-12.044	61.25	4.936E-07	-6.307	64.65	8.452
486	1906.7	8.743E-13	-12.058	61.34	4.786E-07	-6.320	64.80	8.447
488	1910.0	8.463E-13	-12.072	61.43	4.641E-07	-6.333	64.96	8.442
490	1913.4	8.192E-13	-12.087	61.52	4.500E-07	-6.347	65.11	8.437
492	1916.9	7.930E-13	-12.101	61.60	4.364E-07	-6.360	65.27	8.432
494	1920.5	7.677E-13	-12.115	61.69	4.233E-07	-6.373	65.43	8.427
496	1924.0	7.432E-13	-12.129	61.78	4.106E-07	-6.387	65.59	8.422
498	1927.7	7.196E-13	-12.143	61.87	3.982E-07	-6.400	65.75	8.417
500	1931.4	6.967E-13	-12.157	61.95	3.863E-07	-6.413	65.91	8.412

Table A.1-3. 1965 CIRA Atmospheric Properties, 500 to 800 km.
(Source: E-8, Table 2)

Altitude h (km)	Temperature T (K)	Density ρ (gm cm^{-3})	Pressure P (dynes cm^{-2})	Pressure Scale Height H_P (km)	Mean Molecular Weight M
500	1192	8.154E-16	5.193E-06	75.6	15.56
520	1193	6.171E-16	3.998E-06	77.3	15.31
540	1193	4.693E-16	3.097E-06	79.2	15.03
560	1194	3.584E-16	2.414E-06	81.3	14.74
580	1194	2.750E-16	1.894E-06	83.7	14.41
600	1194	2.119E-16	1.497E-06	86.3	14.06
620	1194	1.640E-16	1.192E-06	89.3	13.67
640	1195	1.274E-16	9.564E-07	92.7	13.24
660	1195	9.952E-17	7.742E-07	96.7	12.77
680	1195	7.810E-17	6.325E-07	101.2	12.27
700	1195	6.161E-17	5.216E-07	106.4	11.74
720	1195	4.888E-17	4.344E-07	112.4	11.18
740	1195	3.901E-17	3.654E-07	119.1	10.61
760	1195	3.135E-17	3.105E-07	126.6	10.04
780	1195	2.537E-17	2.664E-07	135.0	9.46
800	1195	2.068E-17	2.309E-07	144.3	8.91

Table A.1-4. Main Regions of the Earth's Atmosphere.
(Source: T-11, Table 2)

Atmospheric Region	Subregion	Layer	Approximate Altitude Range (km)
Homosphere	Troposphere		0 to 12
	Stratosphere		12 to 50
	Mesosphere		50 to 90
		D	60 to 90
Heterosphere	Thermosphere		90 to 550
		E	90 to 105
		F_1	105 to 150
		F_2	150 to 300
	Exosphere		550 to 60,000

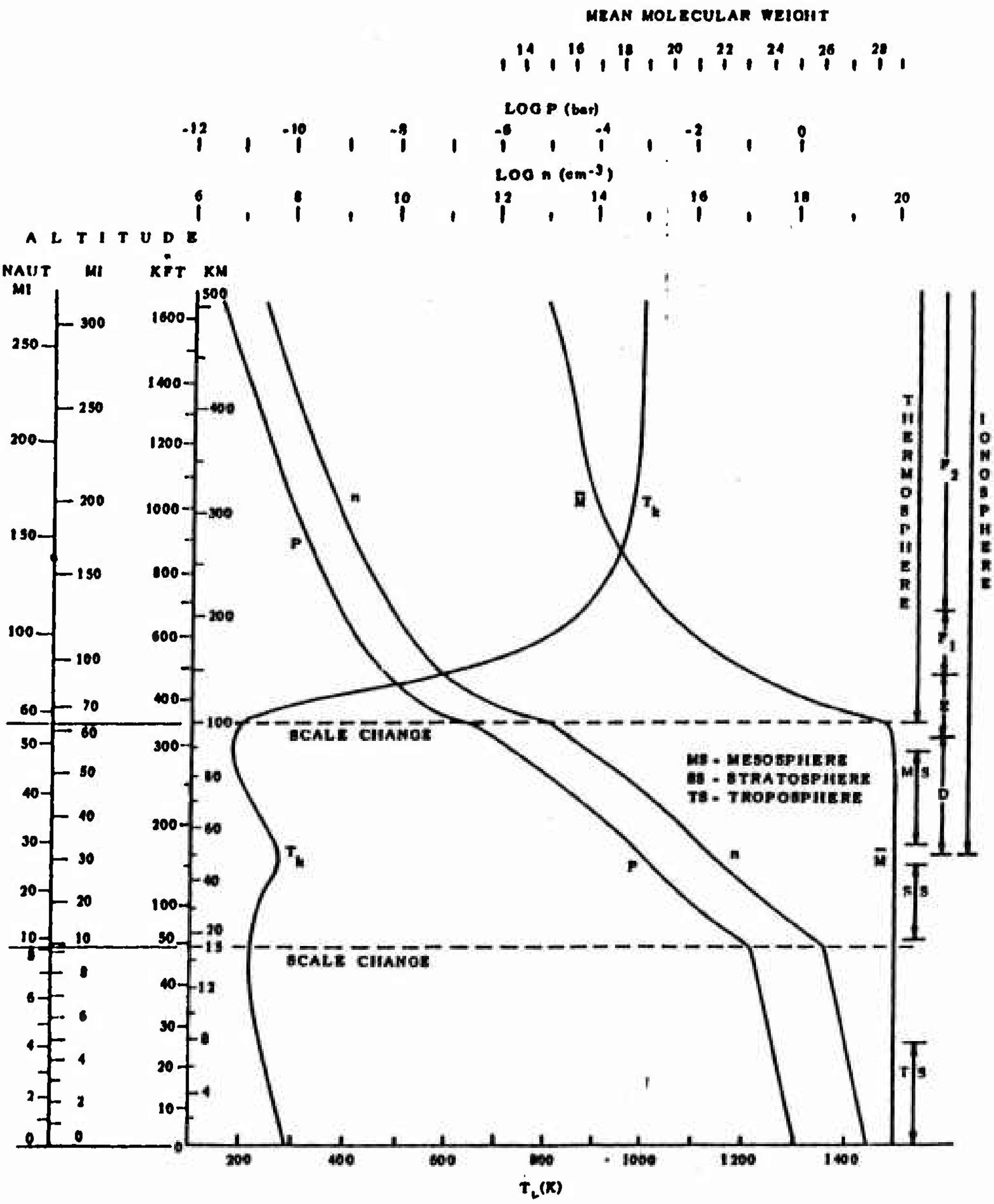

Figure A.1-11. Altitude characteristics and conversions.

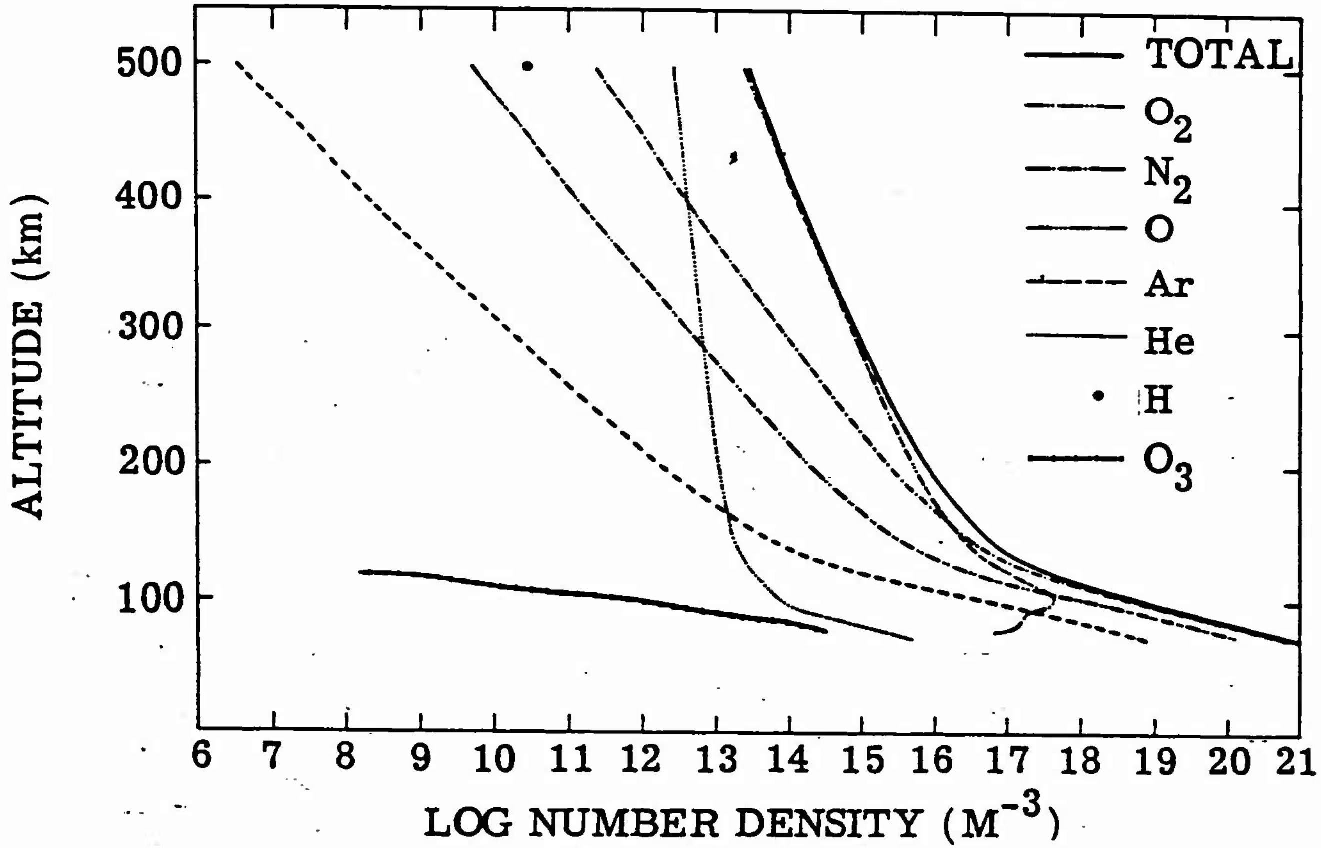

Figure A.2-1. Total number densities and densities of N_2, O_2, O, O_3, Ar, He, and H. (Source: R-2, Figure 7)

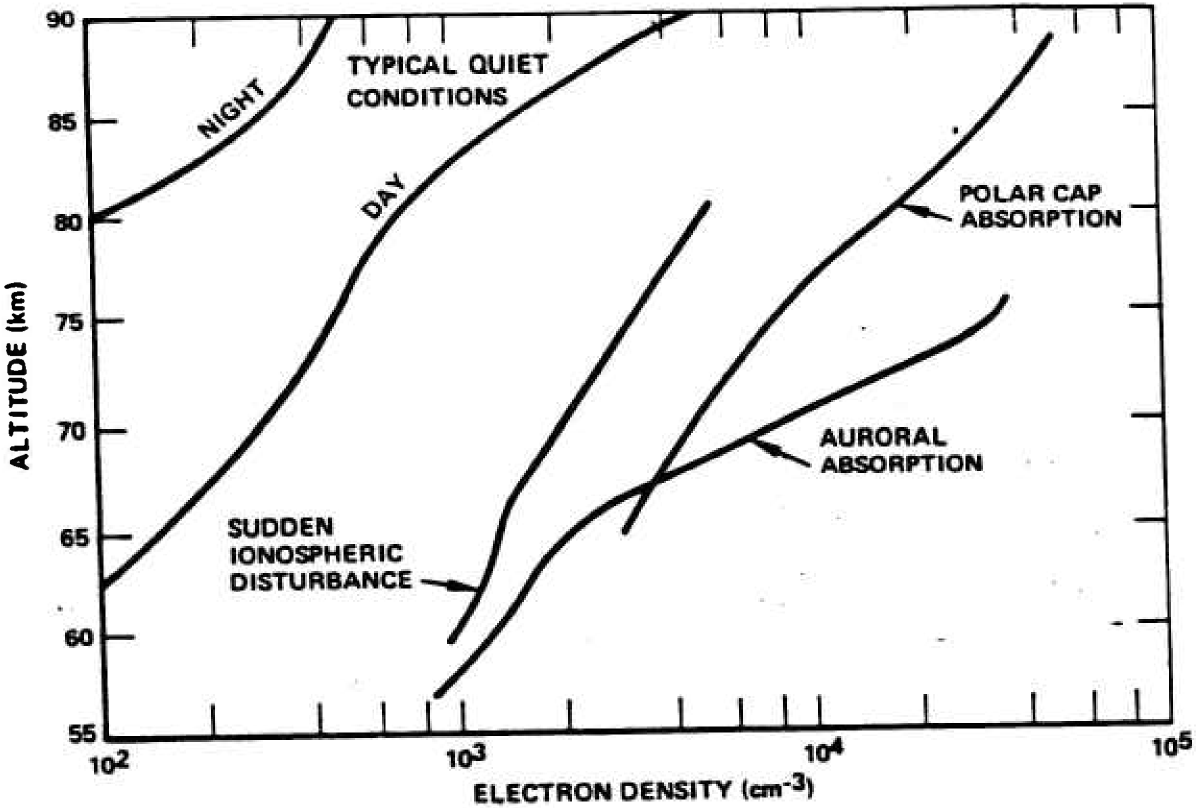

Figure A.2-2. Electron density profiles for the D-region of the ionosphere. (Source: R-5, Figure 5)

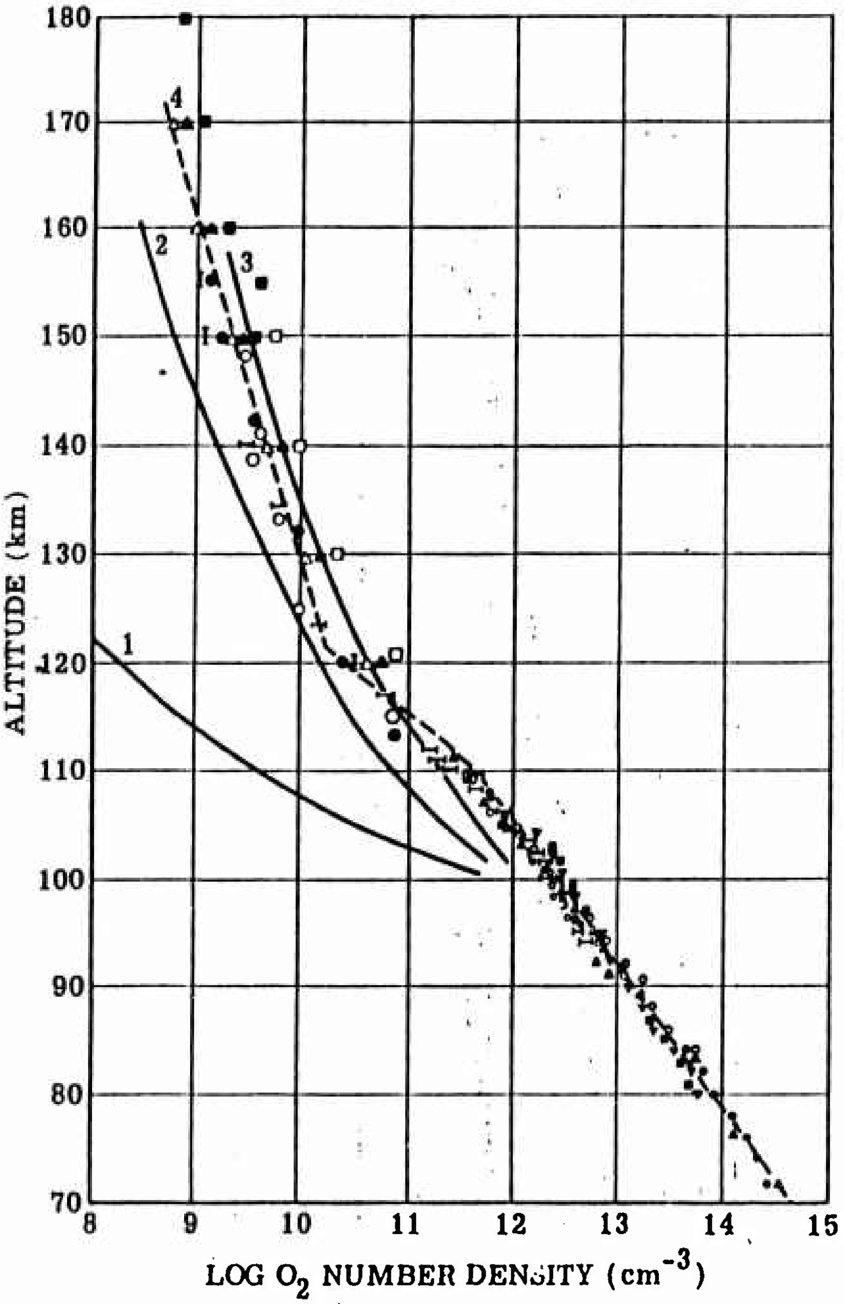

Figure A.2-3. Distribution of molecular oxygen: (1) photochemical equilibrium, (2) diffusive equilibrium, (3) total mixing theory, (4) curve passing through experimental data. (Source: R-3, Figure 7)

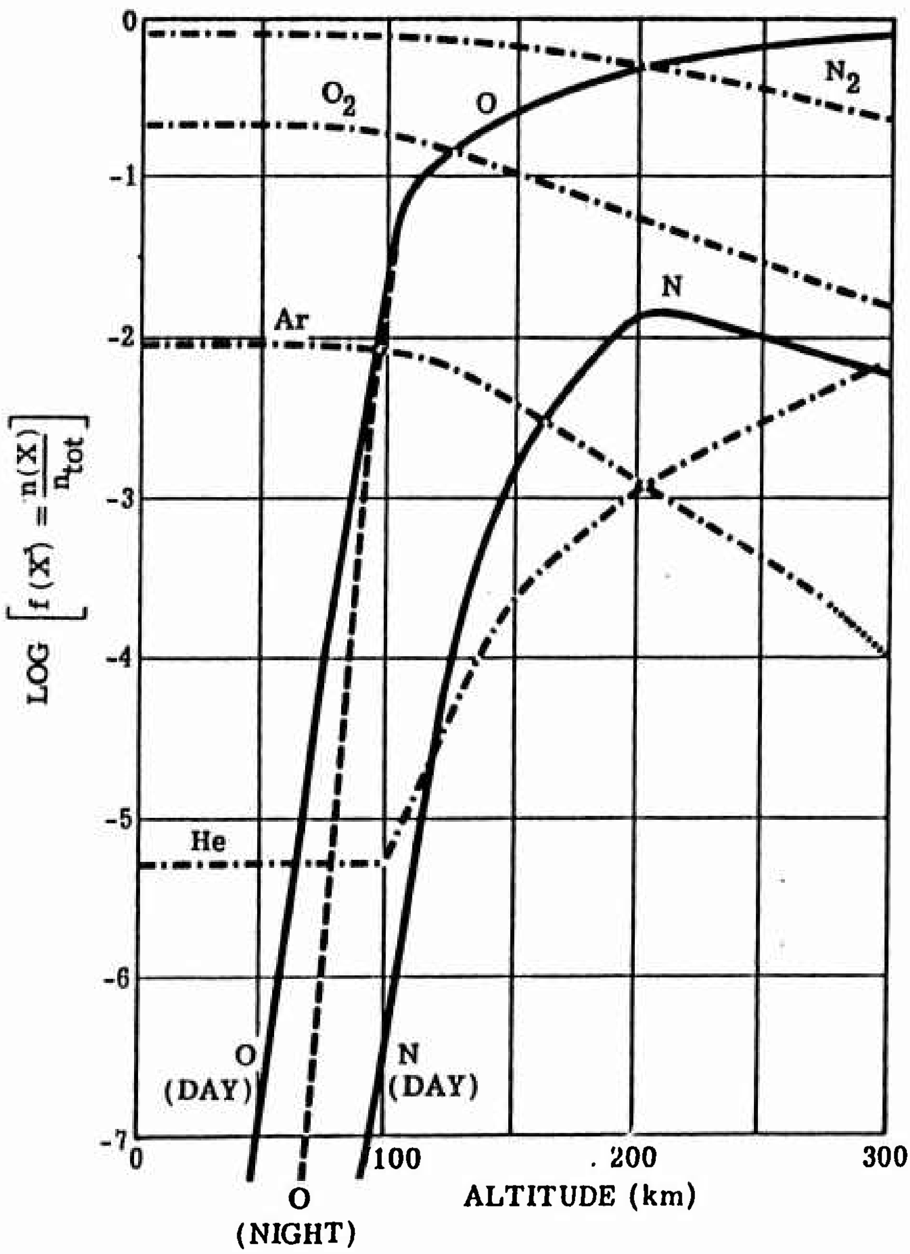

Figure A.2-4. Fractional concentrations of the major neutral species in the atmosphere. (Source: R-4, Figure 1)

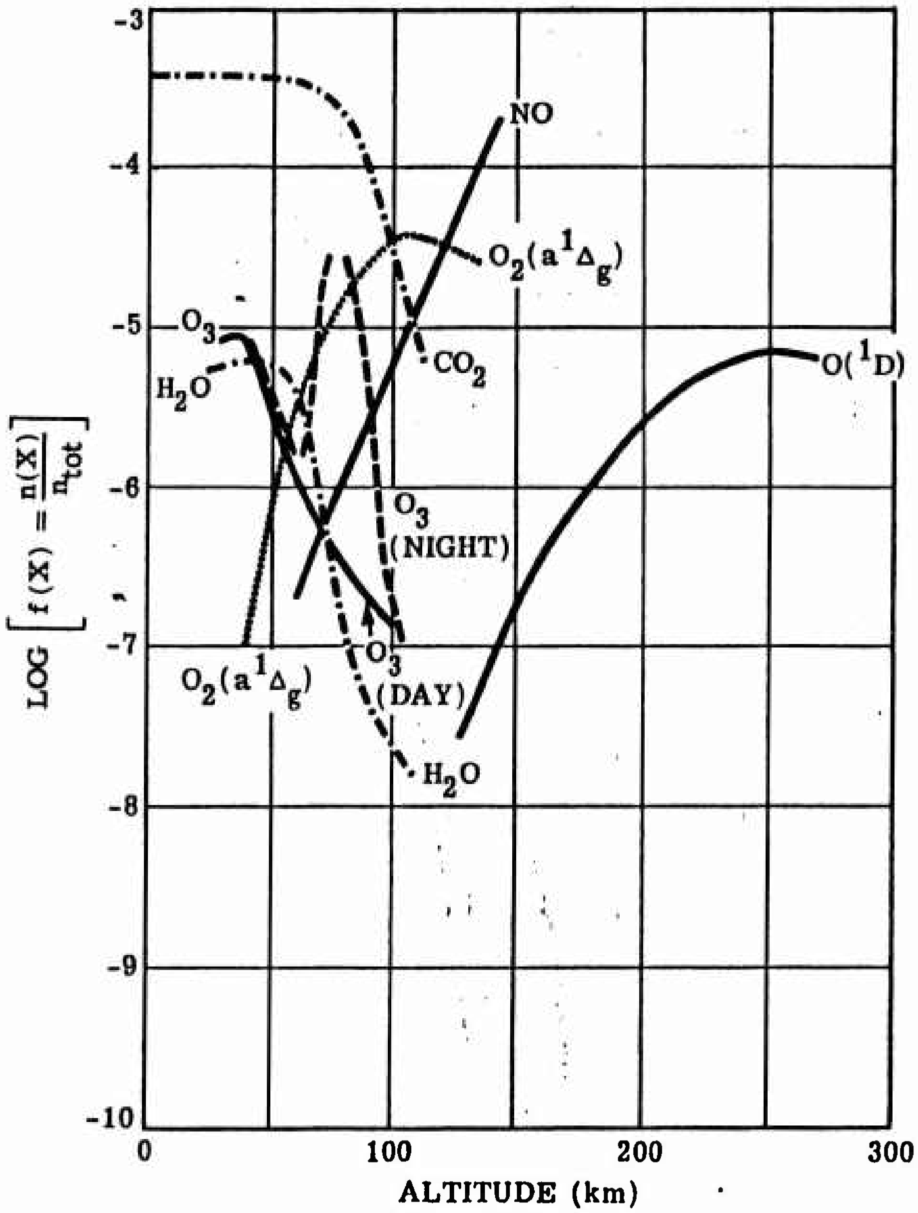

Figure A.2-5. Fractional concentrations of the minor neutral species in the atmosphere. (Source: R-4, Figure 2)

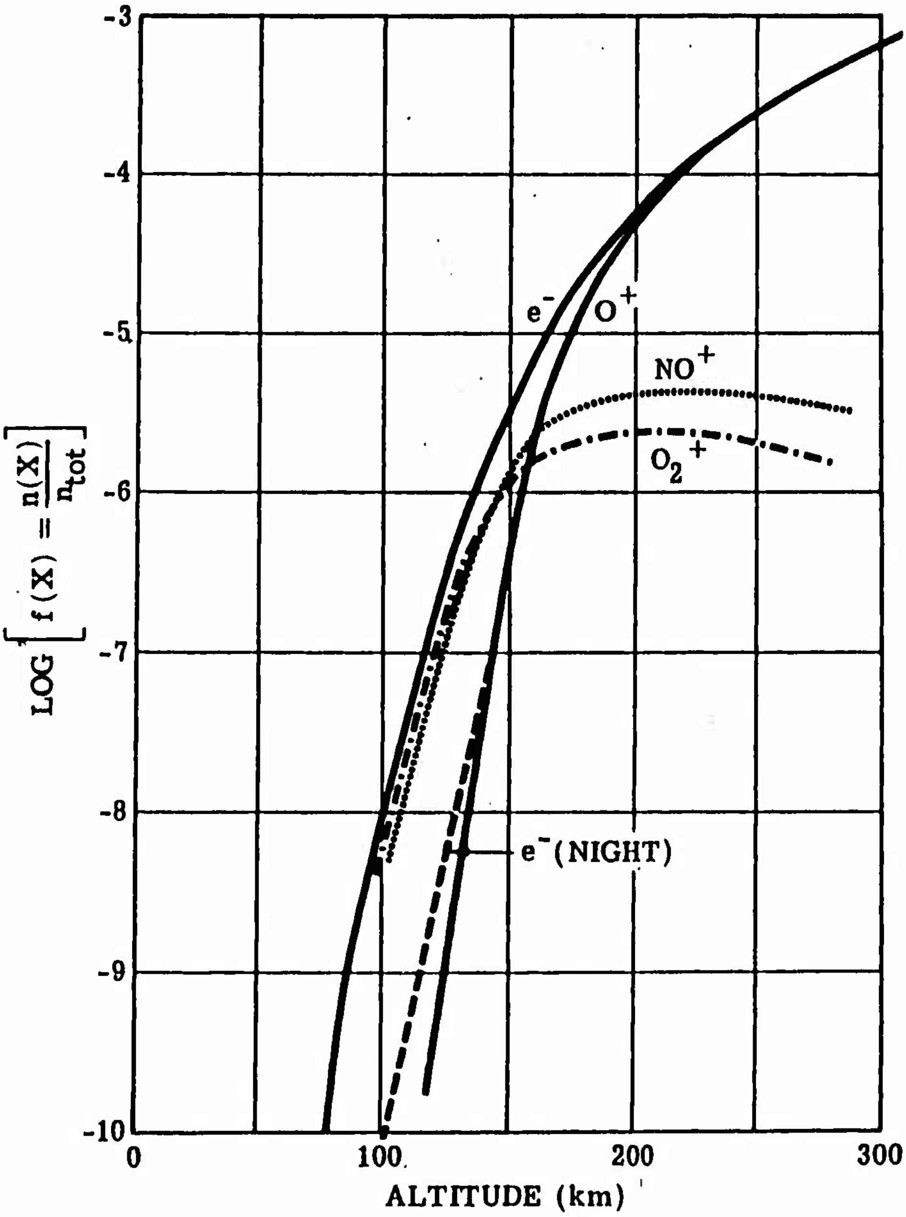

Figure A.2-6. Fractional concentrations of the ionic species in the daytime atmosphere. (Source: R-4, Figure 3)

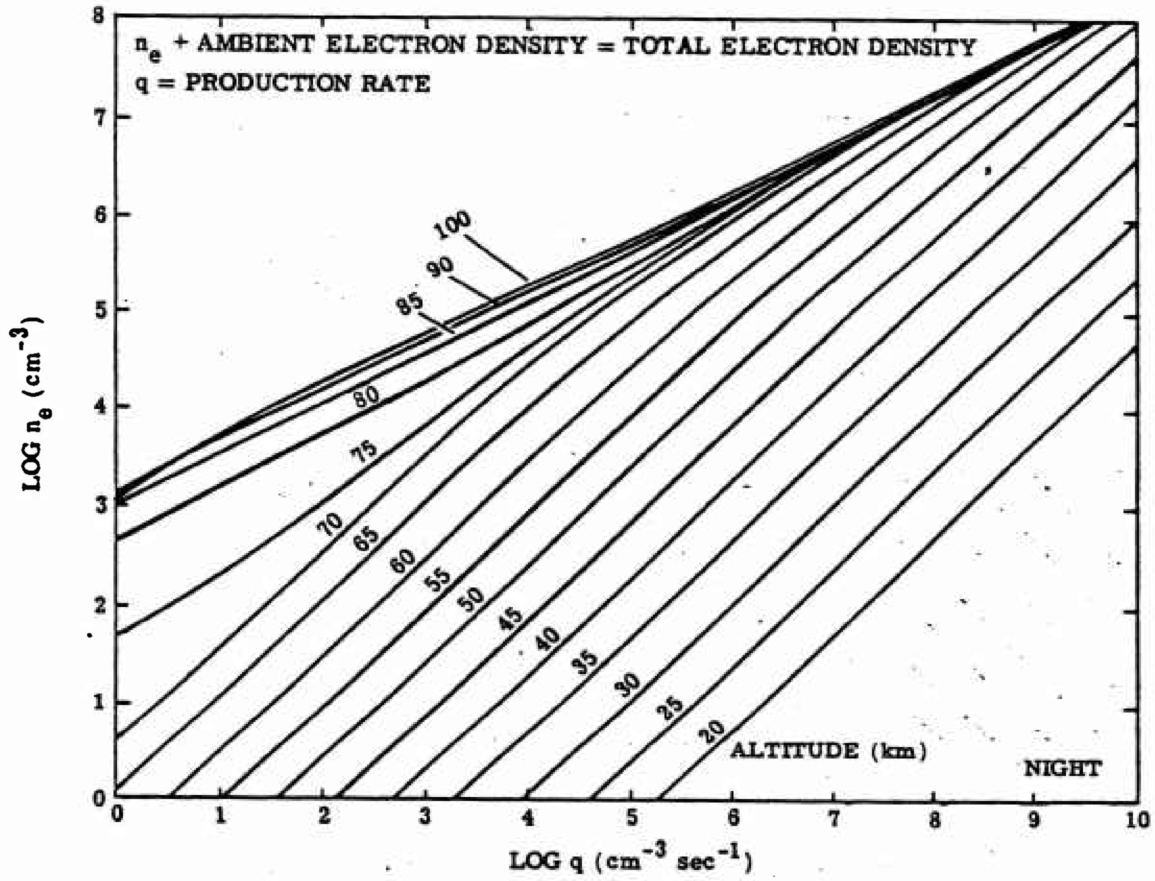

Figure A.2-7. Quasi-equilibrium electron density--nighttime. (Source: E-3, Figure 5)

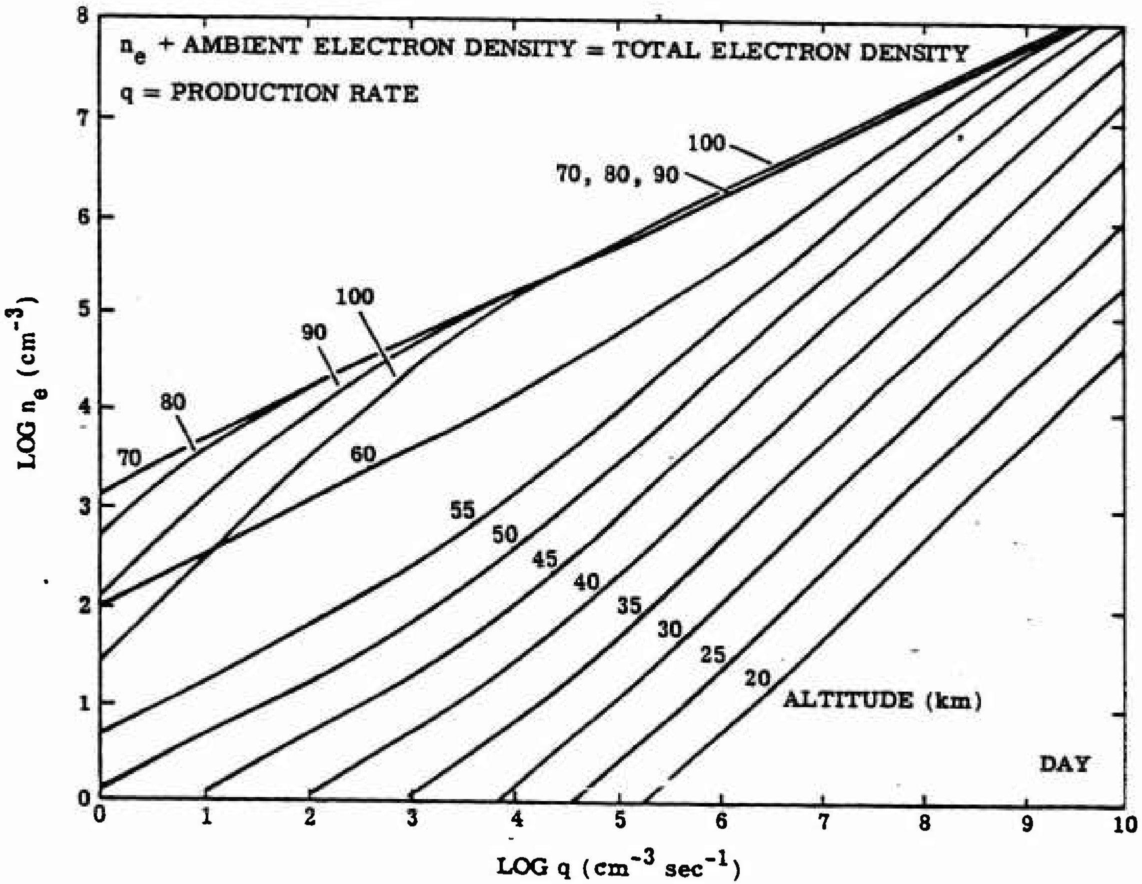

Figure A.2-8. Quasi-equilibrium electron density--daytime. (Source: E-3, Figure 6)

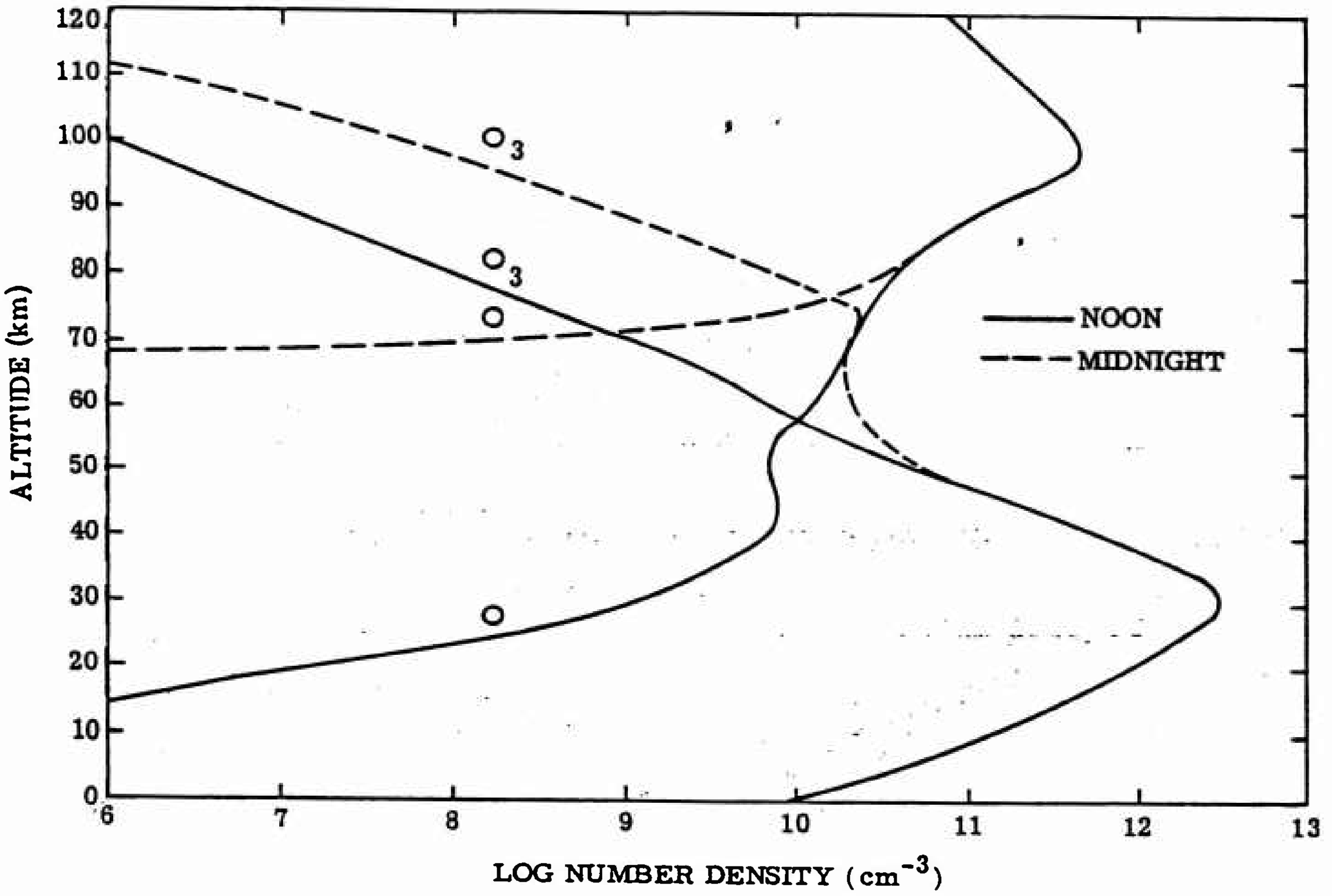

Figure A.2-9. D-region and ozone model. (Source: E-8, Figure 1)

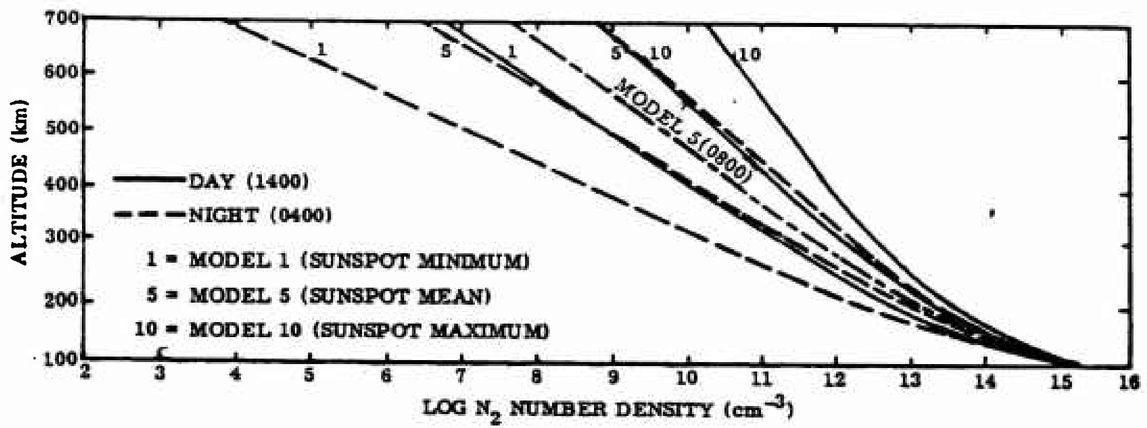

Figure A.2-10. Variation of molecular nitrogen with solar activity. (Source: E-8, Figure 7)

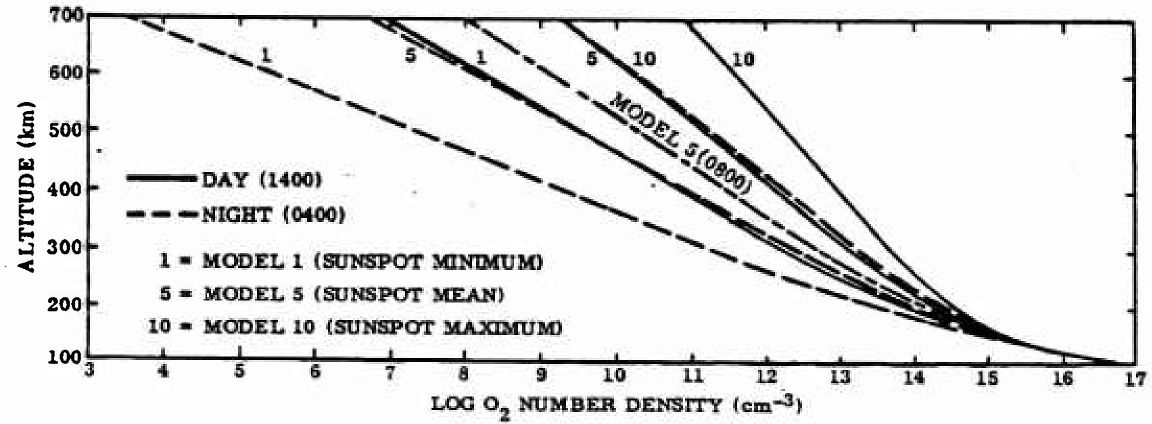

Figure A.2-11. Variation of molecular oxygen with solar activity. (Source: E-8, Figure 8)

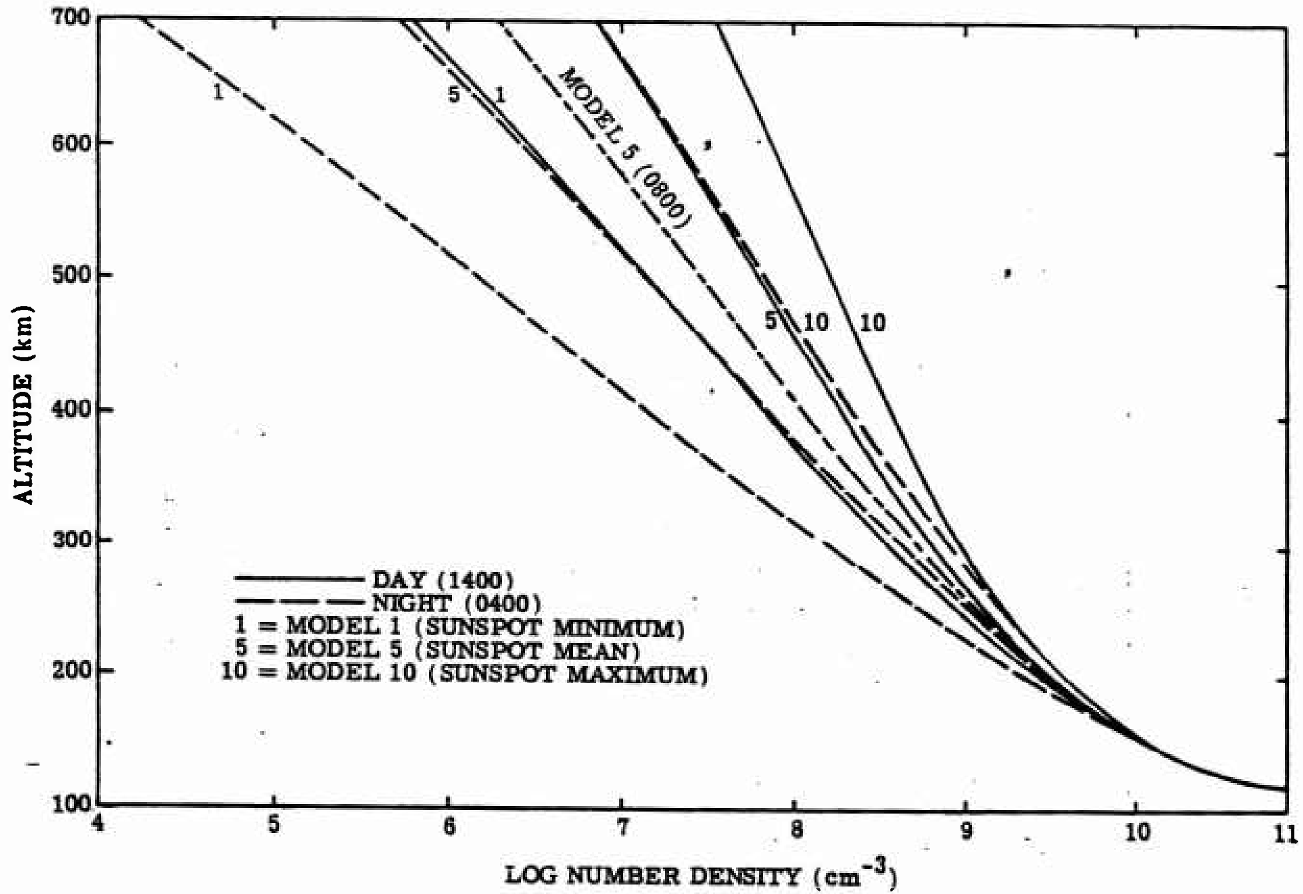

Figure A.2-12. Variation of atomic oxygen with solar activity. (Source: E-8, Figure 9)

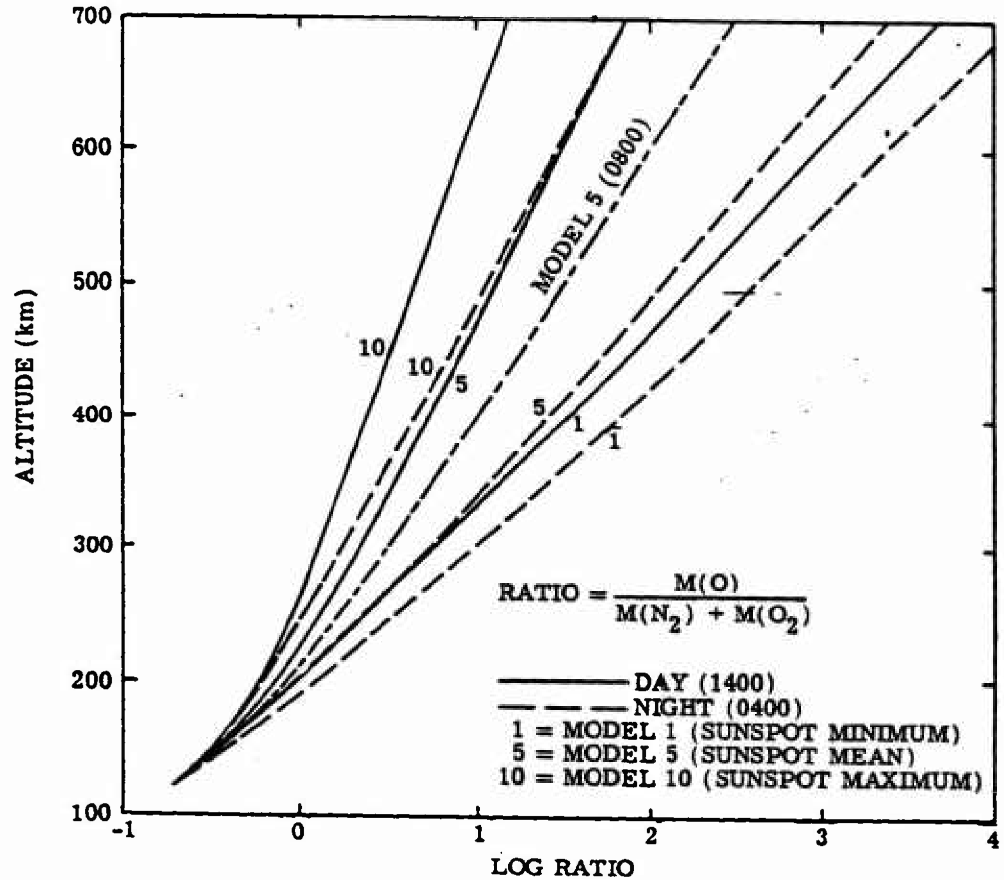

Figure A.2-13. The variation with solar activity of the ratio of atomic oxygen to molecular species. (Source: E-8, Figure 10)

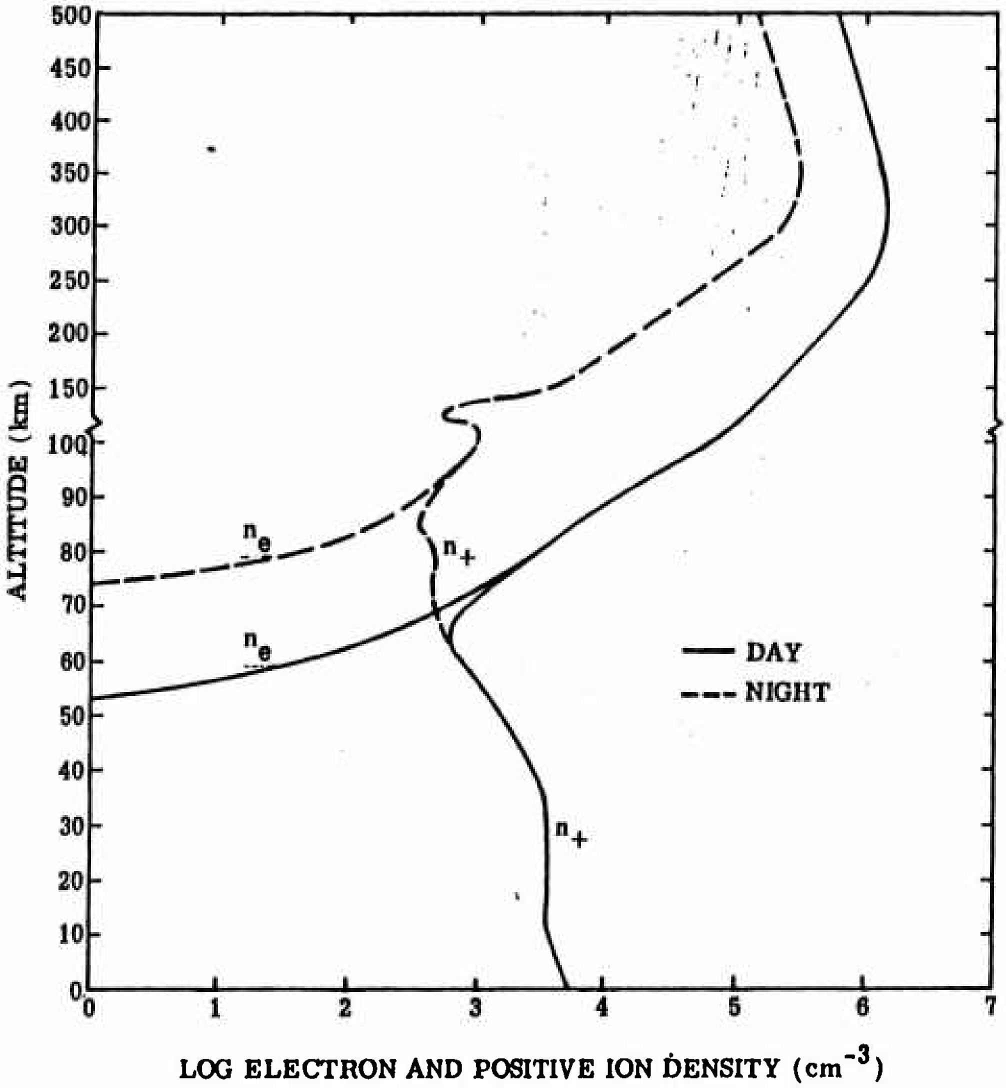

Figure A.2-14. Model Ionosphere. (Source: E-8, Figure 11)

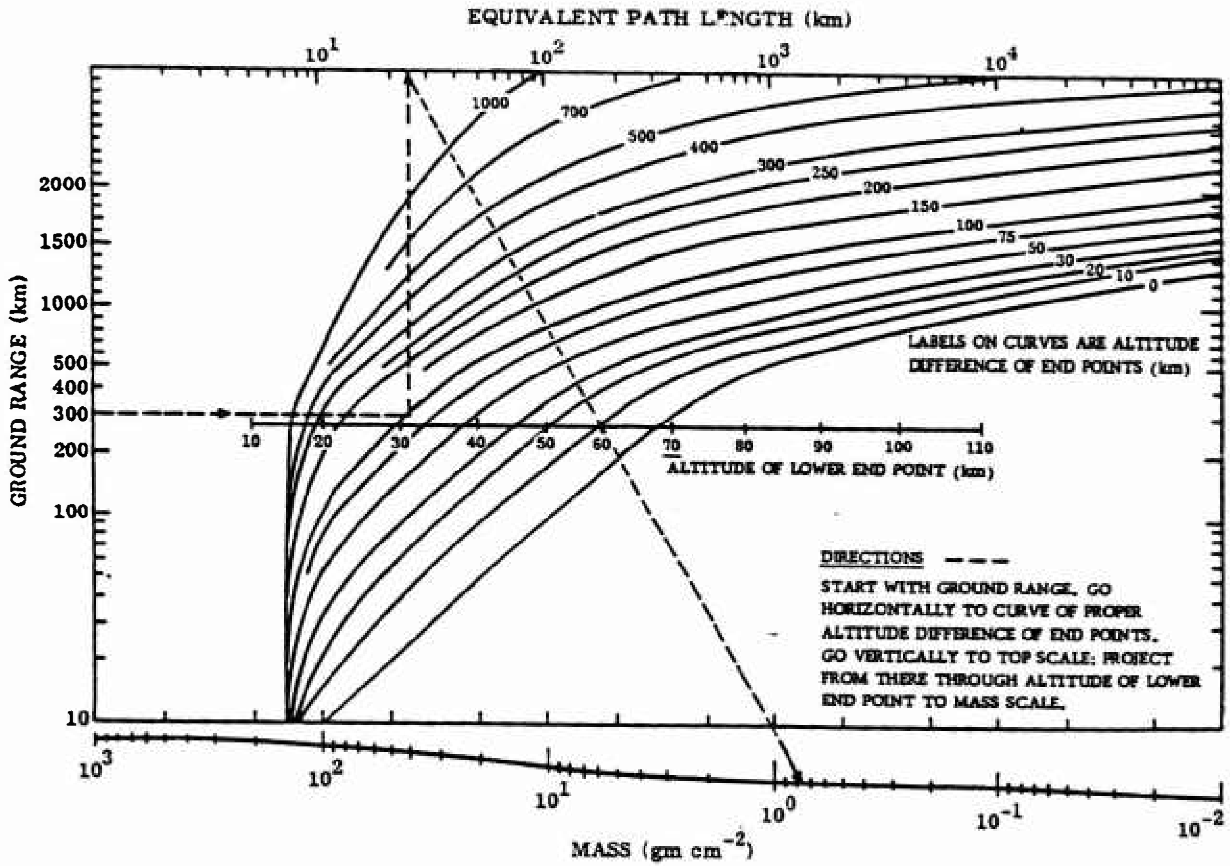

Figure A.2-15. Computation of mass penetrated between two points in the atmosphere. (Source: E-8, Figure 12)

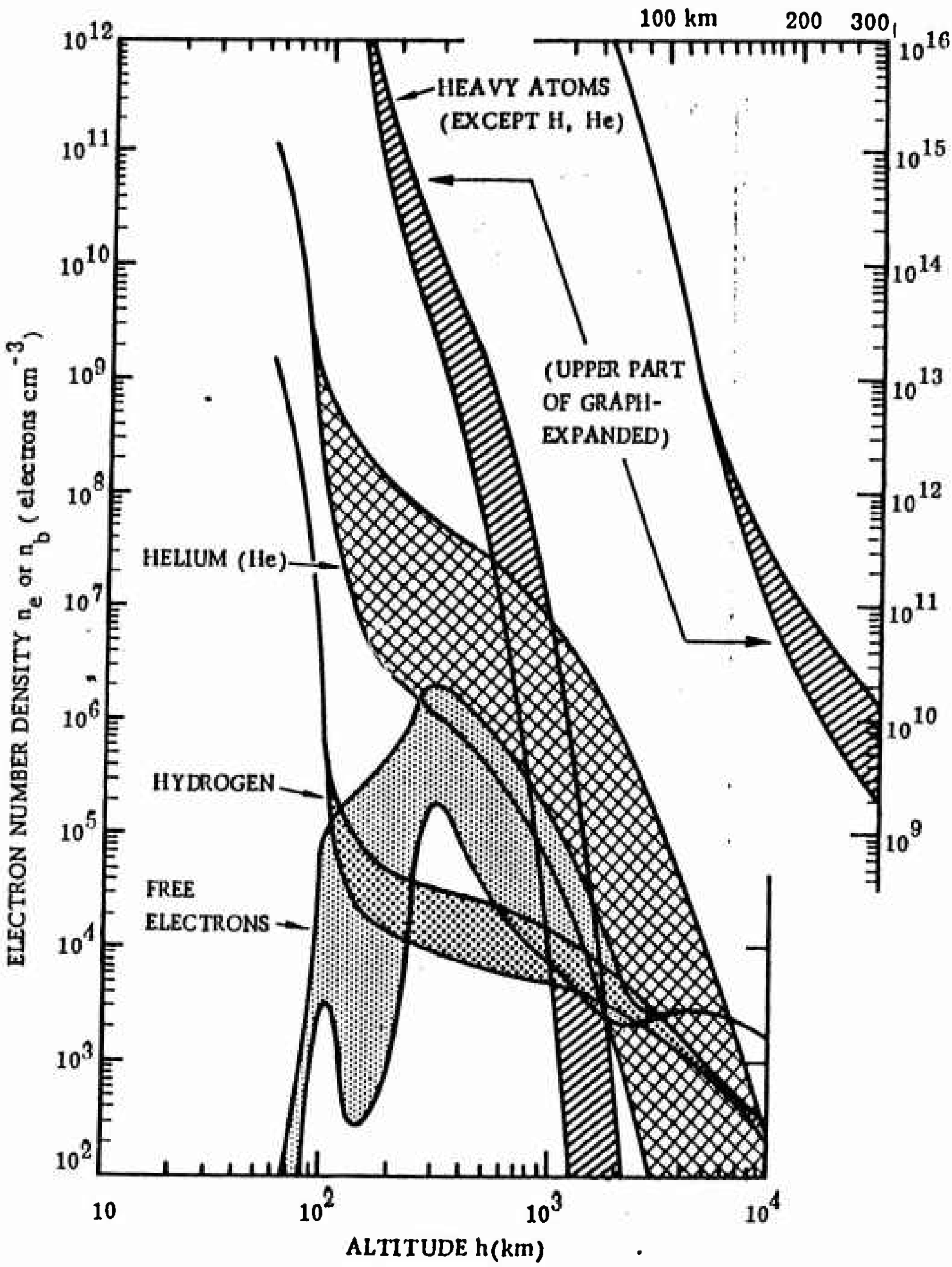

Figure A.2-16. Electron number densities in the atmosphere. The total density of bound electrons contributed by each constituent (usually) falls somewhere within the shaded region. (Source: T-5, Figure 2)

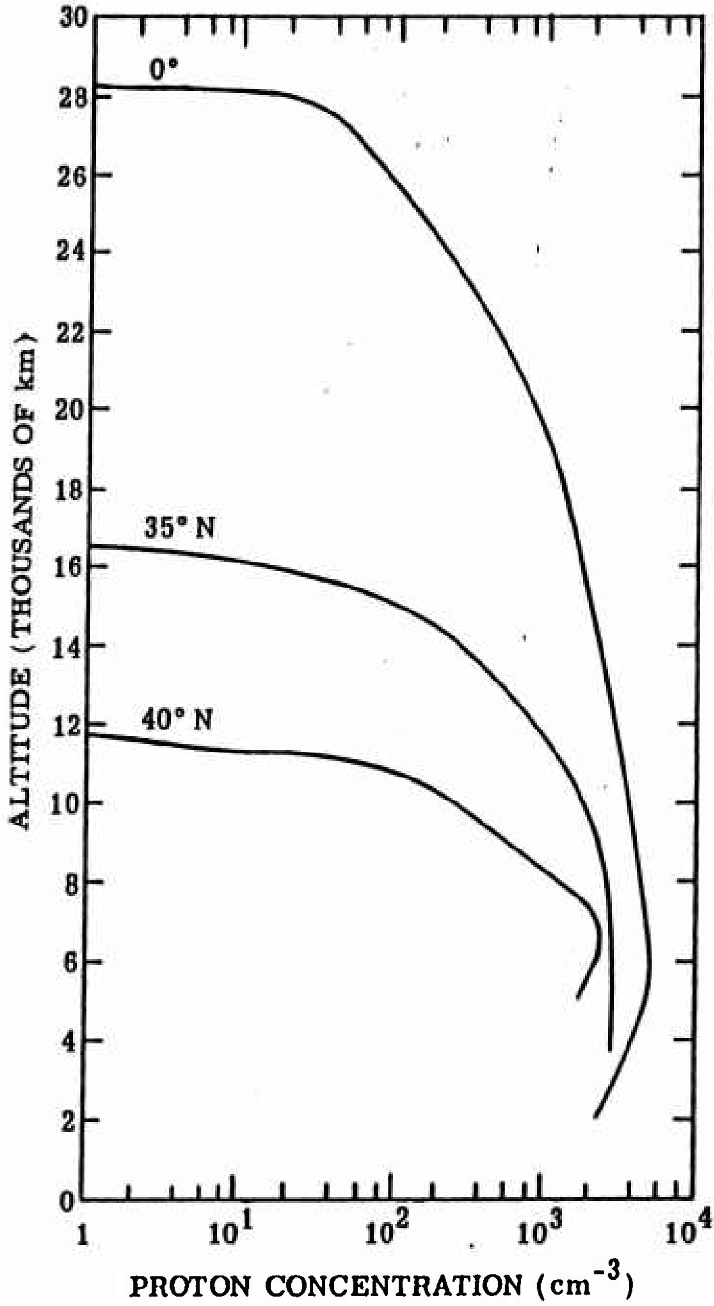

Figure A.2-17. Typical measurements of proton distributions at geomagnetic latitudes of 0° N, 35° N, and 40° N from 2,000 to 30,000 kilometers. (Source: T-11, Figure 9)

Table A.2-1. Kinetic temperature and composition of the Mean Reference Atmosphere, 75 to 120 km. (Source: R-2, Table 2)

HEIGHT KM	TEMP K	MEAN MOL WT	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE) (/M3)	LOG N(O3) (/M3)
75	205.0	28.96	20.832	20.261		18.910	15.659	
76	203.0	28.96	20.765	20.193		18.842	15.591	
77	201.0	28.96	20.698	20.124		18.773	15.523	
78	198.9	28.95	20.630	20.055		18.704	15.454	
79	196.9	28.95	20.562	19.985		18.634	15.385	
80	194.9	28.95	20.492	19.914	16.794	18.563	15.315	14.495
81	192.9	28.94	20.422	19.843	16.896	18.492	15.244	14.434
82	190.9	28.94	20.352	19.771	16.981	18.420	15.172	14.364
83	188.8	28.94	20.280	19.698	17.049	18.347	15.100	14.284
84	186.9	28.93	20.208	19.624	17.102	18.273	15.027	14.195
85	184.9	28.93	20.135	19.550	17.144	18.199	14.954	14.098
86	184.6	28.92	20.058	19.471	17.173	18.120	14.876	13.975
87	184.2	28.91	19.980	19.392	17.194	18.041	14.798	13.845
88	183.9	28.91	19.903	19.312	17.208	17.962	14.721	13.710
89	183.6	28.90	19.825	19.232	17.216	17.882	14.643	13.570
90	183.4	28.89	19.747	19.153	17.220	17.802	14.565	13.425
91	184.1	28.88	19.667	19.070	17.222	17.720	14.486	13.269
92	184.8	28.87	19.587	18.988	17.227	17.638	14.407	13.115
93	186.0	28.86	19.507	18.906	17.235	17.556	14.329	12.959
94	187.2	28.84	19.427	18.823	17.251	17.473	14.253	12.810
95	189.3	28.81	19.346	18.739	17.280	17.389	14.178	12.665
96	190.8	28.77	19.267	18.656	17.334	17.306	14.110	12.549
97	192.9	28.72	19.187	18.570	17.407	17.221	14.050	12.445
98	194.9	28.63	19.107	18.483	17.489	17.133	14.000	12.348
99	197.2	28.51	19.028	18.392	17.562	17.041	13.960	12.236
100	199.4	28.37	18.940	18.299	17.618	16.945	13.928	12.099
101	201.9	28.20	18.853	18.201	17.654	16.842	13.902	11.938
102	204.8	28.03	18.778	18.105	17.670	16.739	13.879	11.766
103	208.4	27.85	18.703	18.009	17.672	16.636	13.855	11.577
104	211.9	27.68	18.630	17.916	17.664	16.536	13.833	11.385
105	216.6	27.51	18.556	17.823	17.647	16.435	13.811	11.178
106	221.2	27.35	18.483	17.734	17.627	16.337	13.791	10.974
107	226.4	27.19	18.411	17.647	17.602	16.241	13.770	10.766
108	232.1	27.03	18.340	17.561	17.573	16.146	13.750	10.555
109	238.4	26.88	18.270	17.479	17.542	16.053	13.730	10.343
110	245.1	26.73	18.200	17.398	17.509	15.961	13.711	10.132
111	252.4	26.59	18.132	17.320	17.475	15.872	13.692	9.920
112	260.1	26.45	18.065	17.245	17.440	15.785	13.673	9.710
113	268.1	26.31	17.999	17.173	17.404	15.701	13.655	9.503
114	276.5	26.18	17.935	17.103	17.368	15.619	13.637	9.299
115	285.2	26.05	17.872	17.036	17.332	15.539	13.620	9.098
116	294.7	25.92	17.811	16.971	17.295	15.461	13.603	8.899
117	304.3	25.80	17.750	16.908	17.259	15.385	13.586	8.703
118	314.2	25.68	17.692	16.847	17.223	15.312	13.569	8.514
119	323.9	25.57	17.635	16.790	17.188	15.242	13.553	8.332
120	334.5	25.45	17.579	16.734	17.153	15.173	13.538	8.167

Table A.2-2. Kinetic temperature and composition of the Mean Reference Atmosphere, 120 to 500 km. (Source: R-2, Table 4)

HEIGHT KM	TEMP K	MEAN MOL WT	NUMBER DENSITY /M3	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE (/M3)
120	334.5	25.45	5.772E+17	17.579	16.734	17.153	15.173	13.538
121	345.3	25.35	5.137E+17	17.524	16.674	17.116	15.102	13.523
122	356.2	25.25	4.589E+17	17.472	16.615	17.080	15.032	13.509
123	367.3	25.15	4.112E+17	17.420	16.558	17.045	14.964	13.496
124	378.5	25.05	3.698E+17	17.370	16.503	17.011	14.898	13.482
125	389.7	24.95	3.336E+17	17.322	16.449	16.978	14.835	13.469
126	400.9	24.85	3.019E+17	17.274	16.397	16.946	14.773	13.457
127	412.1	24.76	2.741E+17	17.229	16.347	16.914	14.712	13.444
128	423.3	24.66	2.496E+17	17.184	16.297	16.884	14.654	13.432
129	434.4	24.57	2.279E+17	17.141	16.249	16.854	14.597	13.421
130	445.4	24.48	2.087E+17	17.098	16.203	16.826	14.541	13.410
131	456.4	24.39	1.916E+17	17.057	16.157	16.798	14.487	13.399
132	467.2	24.31	1.763E+17	17.017	16.113	16.770	14.434	13.388
133	478.0	24.22	1.626E+17	16.978	16.070	16.744	14.383	13.378
134	488.6	24.13	1.503E+17	16.940	16.028	16.718	14.333	13.368
135	499.0	24.05	1.393E+17	16.903	15.987	16.693	14.284	13.358
136	509.4	23.97	1.293E+17	16.867	15.947	16.668	14.236	13.349
137	519.6	23.89	1.203E+17	16.832	15.908	16.645	14.190	13.340
138	529.6	23.81	1.121E+17	16.798	15.870	16.621	14.144	13.331
139	539.4	23.73	1.047E+17	16.764	15.832	16.599	14.099	13.322
140	549.0	23.65	9.793E+16	16.731	15.796	16.577	14.056	13.314
141	558.5	23.57	9.176E+16	16.699	15.760	16.555	14.013	13.306
142	567.8	23.49	8.610E+16	16.667	15.725	16.534	13.971	13.298
143	576.9	23.42	8.092E+16	16.636	15.691	16.513	13.930	13.290
144	585.8	23.35	7.616E+16	16.606	15.657	16.493	13.890	13.282
145	594.5	23.27	7.178E+16	16.577	15.624	16.474	13.850	13.275
146	603.0	23.20	6.774E+16	16.548	15.592	16.454	13.811	13.268
147	611.4	23.13	6.401E+16	16.519	15.560	16.436	13.773	13.261
148	619.5	23.06	6.056E+16	16.491	15.529	16.417	13.736	13.254
149	627.4	22.99	5.736E+16	16.464	15.499	16.399	13.699	13.248
150	635.2	22.92	5.439E+16	16.437	15.469	16.381	13.663	13.241
151	642.8	22.85	5.163E+16	16.410	15.439	16.364	13.627	13.235
152	650.2	22.78	4.906E+16	16.384	15.410	16.347	13.592	13.229
153	657.4	22.71	4.666E+16	16.358	15.381	16.330	13.557	13.223
154	664.4	22.65	4.442E+16	16.333	15.353	16.314	13.523	13.217
155	671.3	22.58	4.233E+16	16.308	15.325	16.298	13.490	13.212
156	678.0	22.51	4.037E+16	16.283	15.298	16.282	13.457	13.206
157	684.5	22.45	3.853E+16	16.259	15.271	16.266	13.424	13.201
158	690.9	22.39	3.681E+16	16.235	15.244	16.251	13.392	13.195
159	697.1	22.32	3.518E+16	16.212	15.218	16.236	13.360	13.190
160	703.1	22.26	3.366E+16	16.189	15.192	16.221	13.328	13.185

Table A.2-2. (Continued)

HEIGHT KM	TEMP K	MEAN MOL WT	NUMBER DENSITY /M3	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE) (/M3)
161	709.0	22.20	3.222E+16	16.166	15.166	16.206	13.297	13.180
162	714.8	22.13	3.087E+16	16.143	15.141	16.192	13.266	13.175
163	720.4	22.07	2.959E+16	16.121	15.115	16.177	13.236	13.170
164	725.9	22.01	2.838E+16	16.099	15.091	16.163	13.205	13.166
165	731.3	21.95	2.723E+16	16.077	15.066	16.150	13.176	13.161
166	736.5	21.89	2.615E+16	16.055	15.042	16.136	13.146	13.156
167	741.6	21.83	2.513E+16	16.034	15.018	16.122	13.117	13.152
168	746.6	21.78	2.416E+16	16.012	14.994	16.109	13.088	13.147
169	751.5	21.72	2.323E+16	15.991	14.970	16.096	13.059	13.143
170	756.2	21.66	2.236E+16	15.971	14.947	16.083	13.031	13.139
171	760.8	21.60	2.152E+16	15.950	14.924	16.070	13.003	13.135
172	765.4	21.55	2.073E+16	15.930	14.901	16.057	12.975	13.130
173	769.8	21.49	1.998E+16	15.909	14.878	16.045	12.947	13.126
174	774.1	21.43	1.926E+16	15.889	14.856	16.032	12.919	13.122
175	778.4	21.38	1.857E+16	15.870	14.834	16.020	12.892	13.118
176	782.5	21.32	1.792E+16	15.850	14.811	16.007	12.865	13.114
177	786.5	21.27	1.730E+16	15.830	14.789	15.995	12.838	13.111
178	790.5	21.22	1.670E+16	15.811	14.768	15.983	12.811	13.107
179	794.4	21.16	1.613E+16	15.792	14.746	15.971	12.785	13.103
180	798.1	21.11	1.559E+16	15.773	14.724	15.960	12.758	13.099
181	801.8	21.06	1.507E+16	15.754	14.703	15.948	12.732	13.096
182	805.5	21.00	1.457E+16	15.735	14.682	15.936	12.706	13.092
183	809.0	20.95	1.409E+16	15.716	14.661	15.925	12.680	13.088
184	812.5	20.90	1.363E+16	15.698	14.640	15.914	12.655	13.085
185	815.9	20.85	1.319E+16	15.679	14.619	15.902	12.629	13.081
186	819.2	20.80	1.277E+16	15.661	14.598	15.891	12.604	13.078
187	822.5	20.75	1.237E+16	15.643	14.578	15.880	12.579	13.075
188	825.7	20.70	1.198E+16	15.625	14.557	15.869	12.554	13.071
189	828.8	20.65	1.161E+16	15.607	14.537	15.858	12.529	13.068
190	831.9	20.60	1.125E+16	15.589	14.517	15.847	12.504	13.064
191	834.9	20.55	1.091E+16	15.571	14.497	15.836	12.479	13.061
192	837.8	20.51	1.058E+16	15.553	14.477	15.825	12.455	13.058
193	840.7	20.46	1.026E+16	15.536	14.457	15.815	12.430	13.055
194	843.5	20.41	9.956E+15	15.518	14.437	15.804	12.406	13.052
195	846.3	20.37	9.661E+15	15.501	14.418	15.794	12.382	13.048
196	849.0	20.32	9.378E+15	15.484	14.398	15.783	12.358	13.045
197	851.7	20.27	9.104E+15	15.466	14.379	15.773	12.334	13.042
198	854.3	20.23	8.841E+15	15.449	14.359	15.762	12.310	13.039
199	856.8	20.18	8.587E+15	15.432	14.340	15.752	12.286	13.036
200	859.3	20.14	8.342E+15	15.415	14.321	15.742	12.262	13.033

Table A.2-2. (Continued)

HEIGHT KM	TEMP K	MEAN MOL WT	NUMBER DENSITY /M3	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE) (/M3)
202	864.2	20.05	7.878E+15	15.382	14.283	15.721	12.215	13.027
204	868.9	19.96	7.445E+15	15.348	14.245	15.701	12.169	13.021
206	873.4	19.88	7.041E+15	15.315	14.207	15.682	12.122	13.015
208	877.8	19.79	6.665E+15	15.282	14.170	15.662	12.077	13.010
210	882.0	19.71	6.312E+15	15.250	14.133	15.642	12.031	13.004
212	886.0	19.63	5.982E+15	15.217	14.096	15.623	11.986	12.998
214	889.9	19.55	5.673E+15	15.185	14.060	15.604	11.941	12.993
216	893.7	19.47	5.384E+15	15.153	14.024	15.585	11.896	12.987
218	897.3	19.39	5.112E+15	15.122	13.988	15.566	11.852	12.982
220	900.7	19.32	4.856E+15	15.090	13.952	15.547	11.807	12.977
222	904.1	19.24	4.616E+15	15.059	13.917	15.529	11.763	12.971
224	907.3	19.17	4.390E+15	15.028	13.881	15.510	11.720	12.966
226	910.5	19.10	4.177E+15	14.997	13.846	15.492	11.676	12.961
228	913.5	19.03	3.977E+15	14.966	13.811	15.474	11.633	12.956
230	916.4	18.96	3.788E+15	14.936	13.777	15.456	11.590	12.951
232	919.2	18.89	3.609E+15	14.905	13.742	15.438	11.547	12.946
234	921.8	18.83	3.441E+15	14.875	13.708	15.420	11.505	12.941
236	924.4	18.76	3.281E+15	14.845	13.674	15.402	11.462	12.936
238	927.0	18.70	3.131E+15	14.815	13.640	15.385	11.420	12.931
240	929.4	18.63	2.988E+15	14.785	13.606	15.367	11.378	12.927
242	931.7	18.57	2.853E+15	14.755	13.572	15.350	11.336	12.922
244	933.9	18.51	2.725E+15	14.726	13.538	15.333	11.295	12.917
246	936.1	18.45	2.604E+15	14.696	13.505	15.315	11.253	12.913
248	938.2	18.39	2.489E+15	14.667	13.472	15.298	11.212	12.908
250	940.2	18.34	2.380E+15	14.638	13.438	15.281	11.171	12.903
252	942.2	18.28	2.277E+15	14.609	13.405	15.264	11.129	12.899
254	944.0	18.23	2.178E+15	14.580	13.372	15.247	11.089	12.894
256	945.8	18.17	2.085E+15	14.551	13.339	15.230	11.048	12.890
258	947.6	18.12	1.996E+15	14.522	13.307	15.214	11.007	12.885
260	949.3	18.07	1.912E+15	14.494	13.274	15.197	10.967	12.881
262	950.9	18.02	1.831E+15	14.465	13.242	15.180	10.926	12.876
264	952.4	17.97	1.755E+15	14.437	13.209	15.164	10.886	12.872
266	953.9	17.92	1.682E+15	14.408	13.177	15.147	10.846	12.867
268	955.4	17.87	1.612E+15	14.380	13.145	15.131	10.806	12.863
270	956.8	17.82	1.546E+15	14.352	13.112	15.114	10.766	12.859
272	958.2	17.78	1.483E+15	14.324	13.080	15.098	10.726	12.854
274	959.5	17.73	1.423E+15	14.295	13.048	15.082	10.686	12.850
276	960.7	17.69	1.365E+15	14.267	13.016	15.065	10.646	12.846
278	961.9	17.65	1.310E+15	14.240	12.985	15.049	10.607	12.842
280	963.1	17.60	1.258E+15	14.212	12.953	15.033	10.567	12.837
282	964.2	17.56	1.208E+15	14.184	12.921	15.017	10.528	12.83[illegible]
284	965.3	17.52	1.160E+15	14.156	12.890	15.001	10.488	12.82[illegible]
286	966.4	17.48	1.114E+15	14.129	12.858	14.985	10.449	12.82[illegible]
288	967.4	17.44	1.071E+15	14.101	12.827	14.969	10.410	12.82[illegible]
290	968.4	17.40	1.029E+15	14.073	12.795	14.953	10.371	12.81[illegible]
292	969.3	17.36	9.891E+14	14.046	12.764	14.937	10.332	12.81[illegible]
294	970.2	17.33	9.508E+14	14.019	12.733	14.921	10.293	12.80[illegible]
296	971.1	17.29	9.142E+14	13.991	12.702	14.906	10.254	12.80[illegible]
298	972.0	17.26	8.792E+14	13.964	12.670	14.890	10.215	12.80[illegible]
300	972.8	17.22	8.456E+14	13.937	12.639	14.874	10.177	12.79[illegible]

Table A.2-2. (Continued)

HEIGHT KM	TEMP K	MEAN MOL WT	NUMBER DENSITY /M3	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE) (/M3)
302	973.6	17.19	8.134E+14	13.909	12.608	14.859	10.138	12.792
304	974.4	17.15	7.826E+14	13.882	12.577	14.843	10.100	12.788
306	975.1	17.12	7.531E+14	13.855	12.546	14.827	10.061	12.784
308	975.8	17.09	7.248E+14	13.828	12.516	14.812	10.023	12.780
310	976.5	17.06	6.977E+14	13.801	12.485	14.796	9.984	12.776
312	977.2	17.02	6.716E+14	13.774	12.454	14.781	9.946	12.772
314	977.8	16.99	6.467E+14	13.747	12.423	14.765	9.908	12.768
316	978.5	16.96	6.227E+14	13.720	12.393	14.750	9.870	12.764
318	979.1	16.93	5.997E+14	13.694	12.362	14.734	9.831	12.760
320	979.7	16.91	5.776E+14	13.667	12.332	14.719	9.793	12.756
322	980.2	16.88	5.565E+14	13.640	12.301	14.703	9.755	12.752
324	980.8	16.85	5.361E+14	13.613	12.271	14.688	9.717	12.748
326	981.3	16.82	5.166E+14	13.587	12.240	14.673	9.679	12.744
328	981.8	16.79	4.978E+14	13.560	12.210	14.657	9.641	12.740
330	982.3	16.77	4.798E+14	13.533	12.179	14.642	9.604	12.736
332	982.8	16.74	4.625E+14	13.507	12.149	14.627	9.566	12.732
334	983.3	16.72	4.458E+14	13.480	12.119	14.612	9.528	12.729
336	983.7	16.69	4.298E+14	13.454	12.089	14.596	9.490	12.725
338	984.1	16.67	4.144E+14	13.427	12.058	14.581	9.453	12.721
340	984.6	16.64	3.997E+14	13.401	12.028	14.566	9.415	12.717
342	985.0	16.62	3.854E+14	13.375	11.998	14.551	9.378	12.713
344	985.4	16.59	3.718E+14	13.348	11.968	14.536	9.340	12.709
346	985.7	16.57	3.586E+14	13.322	11.938	14.521	9.303	12.705
348	986.1	16.55	3.459E+14	13.296	11.908	14.506	9.265	12.702
350	986.5	16.52	3.338E+14	13.269	11.878	14.490	9.228	12.698
352	986.8	16.50	3.220E+14	13.243	11.848	14.475	9.190	12.694
354	987.2	16.48	3.108E+14	13.217	11.818	14.460	9.153	12.690
356	987.5	16.46	2.999E+14	13.191	11.788	14.445	9.116	12.686
358	987.8	16.44	2.894E+14	13.165	11.758	14.430	9.079	12.683
360	988.1	16.42	2.794E+14	13.139	11.729	14.415	9.041	12.679
362	988.4	16.39	2.697E+14	13.112	11.699	14.400	9.004	12.675
364	988.7	16.37	2.604E+14	13.086	11.669	14.386	8.967	12.671
366	989.0	16.35	2.514E+14	13.060	11.639	14.371	8.930	12.667
368	989.2	16.33	2.427E+14	13.034	11.610	14.356	8.893	12.664
370	989.5	16.31	2.344E+14	13.008	11.580	14.341	8.856	12.660
372	989.8	16.29	2.263E+14	12.982	11.550	14.326	8.819	12.656
374	990.0	16.27	2.186E+14	12.956	11.521	14.311	8.782	12.652
376	990.2	16.25	2.111E+14	12.931	11.491	14.296	8.745	12.649
378	990.5	16.23	2.039E+14	12.905	11.462	14.281	8.708	12.645
380	990.7	16.21	1.970E+14	12.879	11.432	14.267	8.672	12.641
382	990.9	16.19	1.903E+14	12.853	11.403	14.252	8.635	12.637
384	991.1	16.18	1.839E+14	12.827	11.373	14.237	8.598	12.634
386	991.3	16.16	1.777E+14	12.801	11.344	14.222	8.561	12.630
388	991.5	16.14	1.717E+14	12.776	11.314	14.208	8.525	12.626
390	991.7	16.12	1.659E+14	12.750	11.285	14.193	8.488	12.622
392	991.9	16.10	1.603E+14	12.724	11.255	14.178	8.451	12.619
394	992.1	16.08	1.550E+14	12.698	11.226	14.163	8.415	12.615
396	992.3	16.06	1.498E+14	12.673	11.197	14.149	8.378	12.611
398	992.5	16.04	1.448E+14	12.647	11.168	14.134	8.342	12.608
400	992.6	16.03	1.400E+14	12.621	11.138	14.119	8.305	12.604

Table A.2-2. (Continued)

HEIGHT KM	TEMP K	MEAN MOL WT	NUMBER DENSITY /M3	LOG N(N2) (/M3)	LOG N(O2) (/M3)	LOG N(O) (/M3)	LOG N(AR) (/M3)	LOG N(HE) (/M3)
402	992.8	16.01	1.353E+14	12.596	11.109	14.105	8.269	12.600
404	993.0	15.99	1.308E+14	12.570	11.080	14.090	8.232	12.596
406	993.1	15.97	1.265E+14	12.545	11.051	14.075	8.196	12.593
408	993.3	15.95	1.223E+14	12.519	11.021	14.061	8.159	12.589
410	993.4	15.93	1.183E+14	12.494	10.992	14.046	8.123	12.585
412	993.6	15.92	1.144E+14	12.468	10.963	14.032	8.087	12.582
414	993.7	15.90	1.107E+14	12.443	10.934	14.017	8.050	12.578
416	993.8	15.88	1.070E+14	12.417	10.905	14.002	8.014	12.574
418	994.0	15.86	1.035E+14	12.392	10.876	13.988	7.978	12.571
420	994.1	15.84	1.001E+14	12.366	10.847	13.973	7.941	12.567
422	994.2	15.82	9.689E+13	12.341	10.818	13.959	7.905	12.563
424	994.3	15.81	9.374E+13	12.316	10.789	13.944	7.869	12.560
426	994.5	15.79	9.070E+13	12.290	10.760	13.930	7.833	12.556
428	994.6	15.77	8.776E+13	12.265	10.731	13.915	7.797	12.553
430	994.7	15.75	8.493E+13	12.239	10.702	13.901	7.761	12.549
432	994.8	15.73	8.219E+13	12.214	10.673	13.886	7.725	12.545
434	994.9	15.71	7.954E+13	12.189	10.644	13.872	7.689	12.542
436	995.0	15.69	7.699E+13	12.164	10.615	13.857	7.653	12.538
438	995.1	15.67	7.452E+13	12.138	10.587	13.843	7.617	12.534
440	995.2	15.65	7.213E+13	12.113	10.558	13.829	7.581	12.531
442	995.3	15.63	6.983E+13	12.088	10.529	13.814	7.545	12.527
444	995.4	15.61	6.760E+13	12.063	10.500	13.800	7.509	12.523
446	995.5	15.59	6.545E+13	12.038	10.471	13.785	7.473	12.520
448	995.6	15.57	6.337E+13	12.012	10.443	13.771	7.437	12.516
450	995.7	15.55	6.136E+13	11.987	10.414	13.757	7.401	12.513
452	995.8	15.53	5.942E+13	11.962	10.385	13.742	7.365	12.509
454	995.8	15.51	5.755E+13	11.937	10.357	13.728	7.330	12.505
456	995.9	15.49	5.574E+13	11.912	10.328	13.713	7.294	12.502
458	996.0	15.47	5.399E+13	11.887	10.299	13.699	7.258	12.498
460	996.1	15.45	5.229E+13	11.862	10.271	13.685	7.222	12.495
462	996.2	15.43	5.066E+13	11.837	10.242	13.670	7.187	12.491
464	996.2	15.40	4.907E+13	11.812	10.214	13.656	7.151	12.487
466	996.3	15.38	4.754E+13	11.787	10.185	13.642	7.115	12.484
468	996.4	15.36	4.607E+13	11.762	10.157	13.628	7.080	12.480
470	996.4	15.34	4.464E+13	11.737	10.128	13.613	7.044	12.477
472	996.5	15.31	4.325E+13	11.712	10.100	13.599	7.009	12.473
474	996.6	15.29	4.192E+13	11.687	10.071	13.585	6.973	12.470
476	996.6	15.27	4.063E+13	11.662	10.043	13.571	6.938	12.466
478	996.7	15.24	3.938E+13	11.637	10.014	13.556	6.902	12.462
480	996.8	15.22	3.817E+13	11.612	9.986	13.542	6.867	12.459
482	996.8	15.19	3.700E+13	11.587	9.957	13.528	6.831	12.455
484	996.9	15.17	3.587E+13	11.563	9.929	13.514	6.796	12.452
486	996.9	15.14	3.478E+13	11.538	9.901	13.500	6.760	12.448
488	997.0	15.12	3.372E+13	11.513	9.872	13.485	6.725	12.445
490	997.0	15.09	3.269E+13	11.488	9.844	13.471	6.690	12.441
492	997.1	15.06	3.171E+13	11.463	9.816	13.457	6.654	12.437
494	997.1	15.04	3.075E+13	11.439	9.787	13.443	6.619	12.434
496	997.2	15.01	2.982E+13	11.414	9.759	13.429	6.584	12.430
498	997.2	14.98	2.893E+13	11.389	9.731	13.415	6.548	12.427
500	997.3	14.95	2.806E+13	11.364	9.703	13.400	6.513	12.423

Table A.2-3. 1965 CIRA Atmosphere Composition, 500 to 800 km.
(Source: E-8, Table 2)

Altitude h (km)	$n(N_2)$ (cm^{-3})	(nO_2) (cm^{-3})	n(O) (cm^{-3})	n(He) (cm^{-3})	n(H) (cm^{-3})
500	9.858E 05	3.507E 04	2.836E 07	2.180E 06	8.737E 03
520	6.128E 05	2.038E 04	2.161E 07	2.037E 06	8.588E 03
540	3.821E 05	1.188E 04	1.650E 07	1.903E 06	8.442E 03
560	2.390E 05	6.952E 03	1.262E 07	1.780E 06	8.300E 03
580	1.499E 05	4.081E 03	9.667E 06	1.665E 06	8.162E 03
600	9.428E 04	2.404E 03	7.418E 06	1.558E 06	8.027E 03
620	5.947E 04	1.420E 03	5.701E 06	1.458E 06	7.895E 03
640	3.762E 04	8.417E 02	4.389E 06	1.366E 06	7.766E 03
660	2.386E 04	5.004E 02	3.384E 06	1.280E 06	7.640E 03
680	1.517E 04	2.984E 02	2.613E 06	1.200E 06	7.518E 03
700	9.673E 03	1.785E 02	2.021E 06	1.125E 06	7.397E 03
720	6.184E 03	1.071E 02	1.565E 06	1.055E 06	7.280E 03
740	3.963E 03	6.442E 01	1.214E 06	9.902E 05	7.165E 03
760	2.546E 03	3.887E 01	9.429E 05	9.295E 05	7.052E 03
780	1.640E 03	2.352E 01	7.334E 05	8.729E 05	6.942E 03
800	1.059E 03	1.427E 01	5.713E 05	8.200E 05	6.834E 03

Table A.2-4. Proton concentration versus altitude and geomagnetic latitude. (Source: T-11, Table 13)

Altitude (km)	0° (cm^{-3})	35° N (cm^{-3})	40° N (cm^{-3})
2,000	2.3(3)	--	--
3,000	3.1(3)	--	--
4,000	3.8(3)	2.8(3)	--
5,000	5.2(3)	2.8(3)	1.7(3)
6,000	5.1(3)	2.7(3)	2.3(3)
7,000	4.6(3)	2.6(3)	2.3(3)
8,000	4.0(3)	2.5(3)	1.3(3)
9,000	3.8(3)	2.1(3)	5.2(2)
10,000	3.5(3)	1.5(3)	2.2(2)
11,000	3.1(3)	1.3(3)	6.1(1)
12,000	2.9(3)	8.0(2)	--
14,000	2.3(3)	2.8(2)	--
16,000	1.7(3)	1.5(1)	--
18,000	1.3(3)	--	--
20,000	9.0(2)	--	--
22,000	4.9(2)	--	--
24,000	2.1(2)	--	--
26,000	5.6(1)	--	--
28,000	1.8(1)	--	--

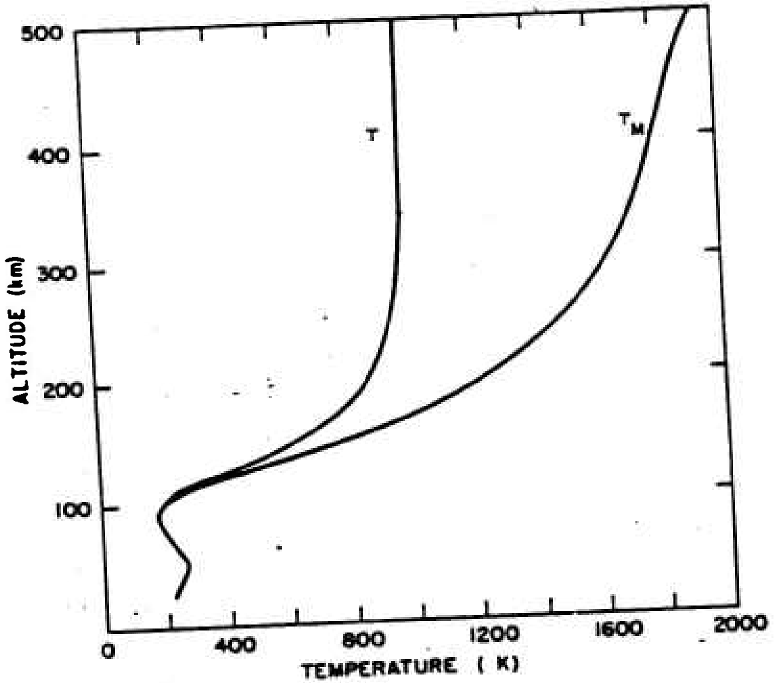

Figure A.3-1. Kinetic temperatures (T) and molecular-scale temperatures (T_M) of the mean atmosphere. (Source: R-2, Figure 2)

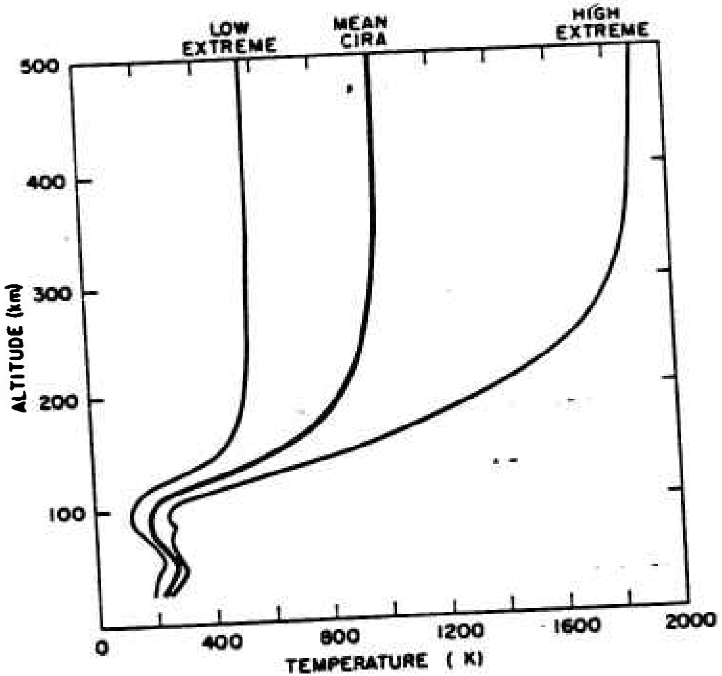

Figure A.3-2. Mean CIRA temperatures and low extreme and high extreme temperatures. (Source: R-2, Figure 3)

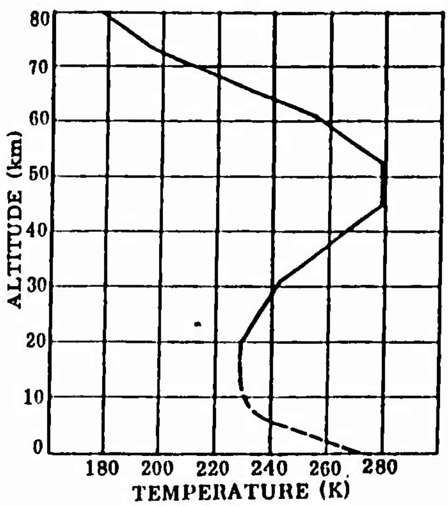

Figure A.3-3. Mean June-July temperature profile for 80° N. (Source: R-2, Figure 8)

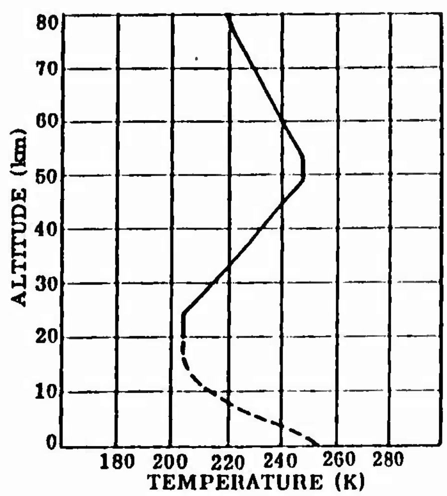

Figure A.3-4. Mean December-January temperature profile for 80° N. (Source: R-2, Figure 9)

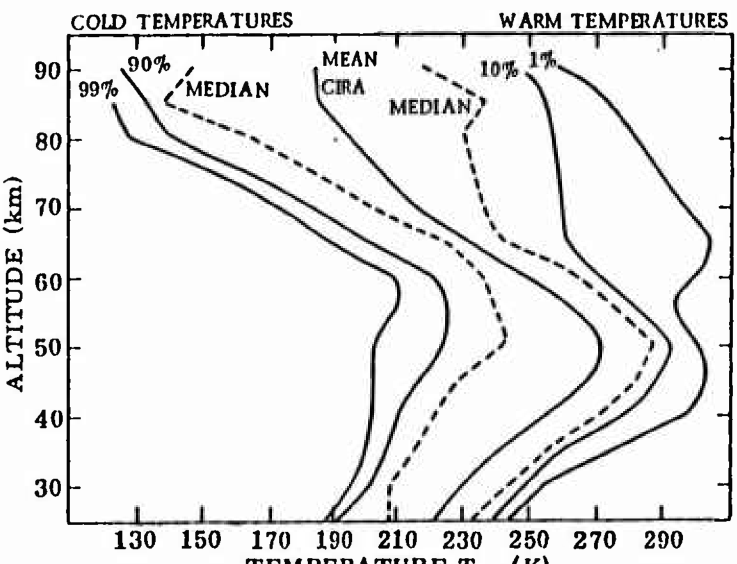

Figure A.3-5. Mean CIRA temperatures, temperatures which are exceeded 50, 10, and 1% of the time during warmest months and temperatures exceeded 50, 90, and 99% of the time during coldest months at latitudes between 0° and 80° N. (Source: R-2, Figure 10)

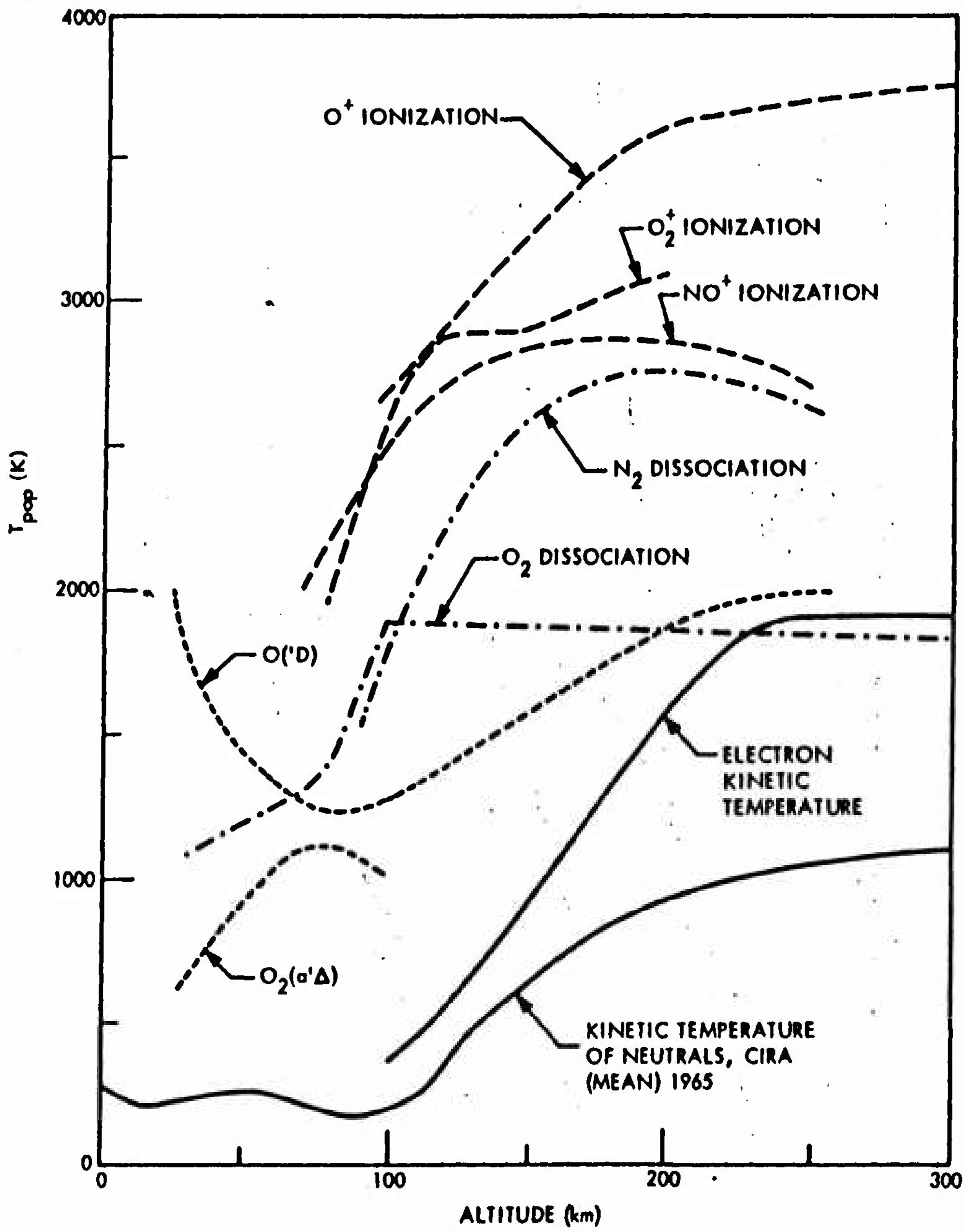

Figure A.3-6. Population temperatures of atmospheric species. (Source: R-4, Figure 4)

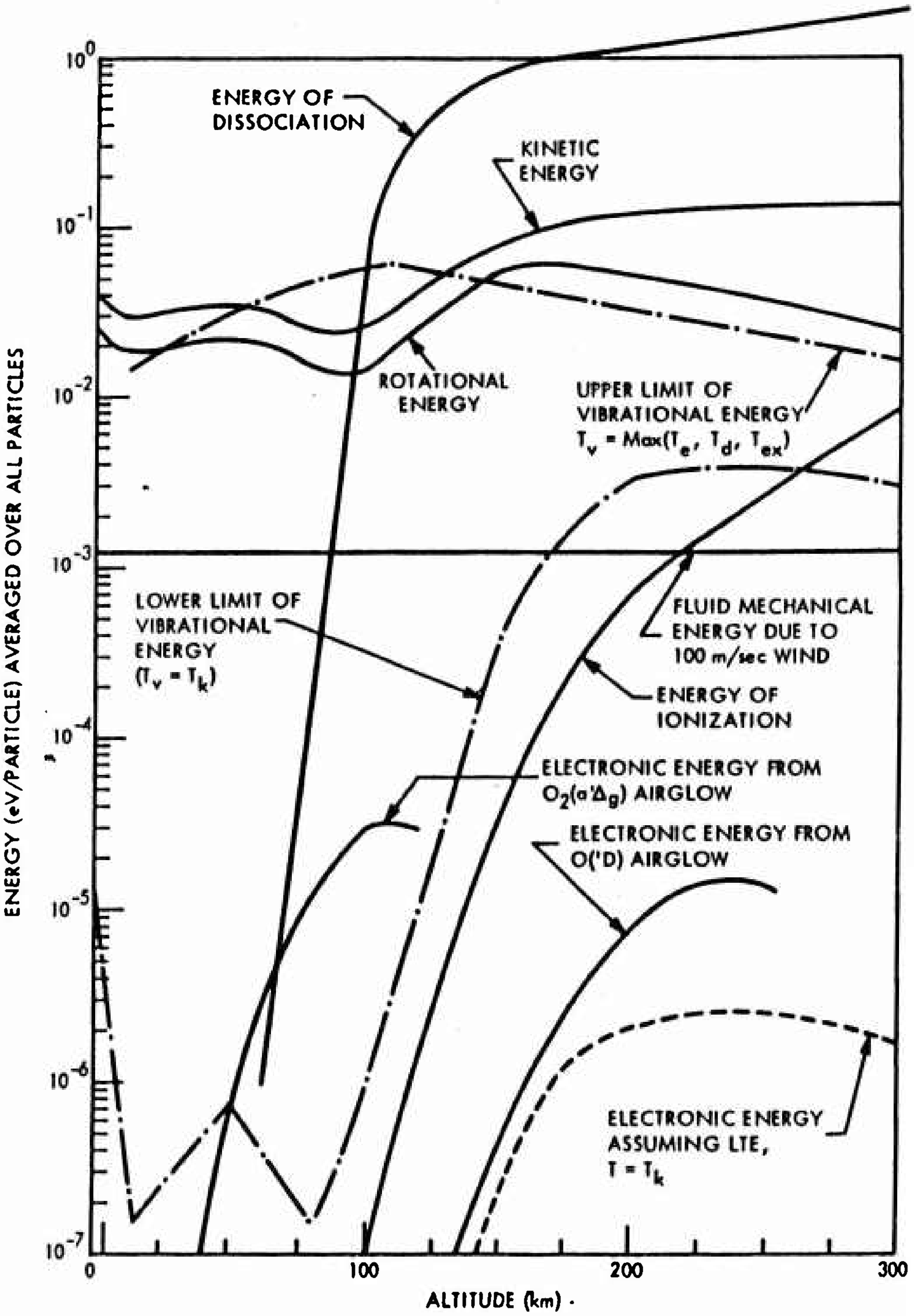

Figure A.3-7. Distribution of energy among different degrees of freedom. (Source: R-4, Figure 5)

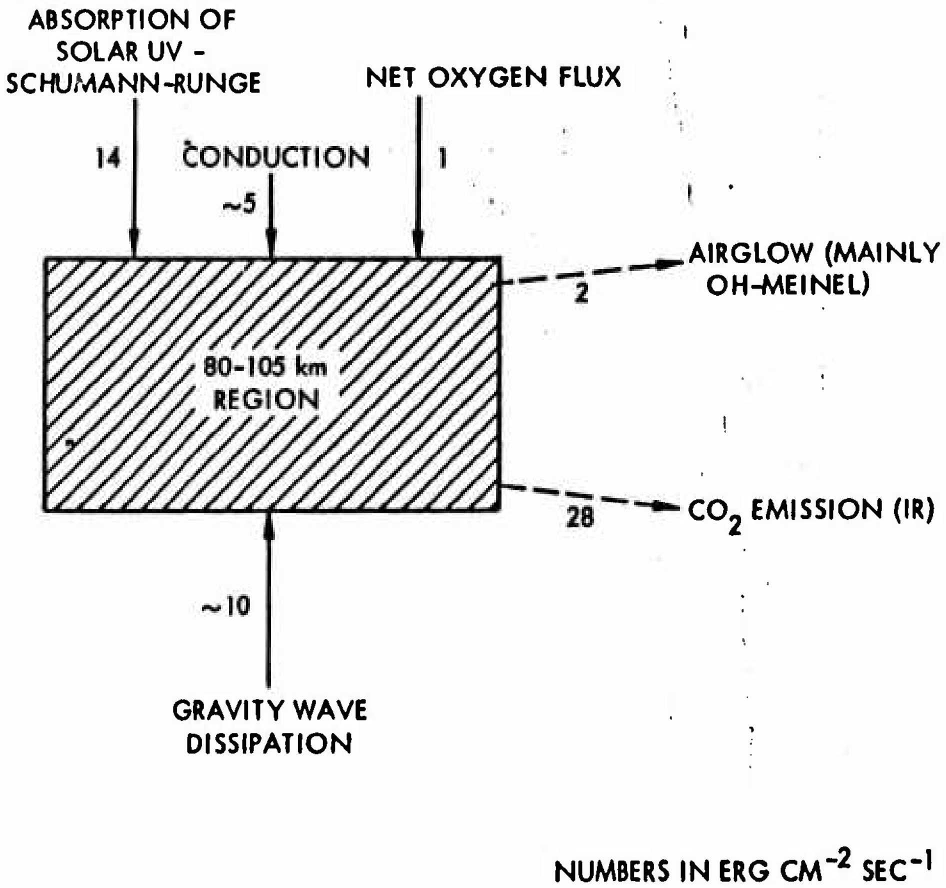

Figure A.3-8. Schematic heat budget constituents between 80 and 105 km. (Source: R-4, Figure 6)

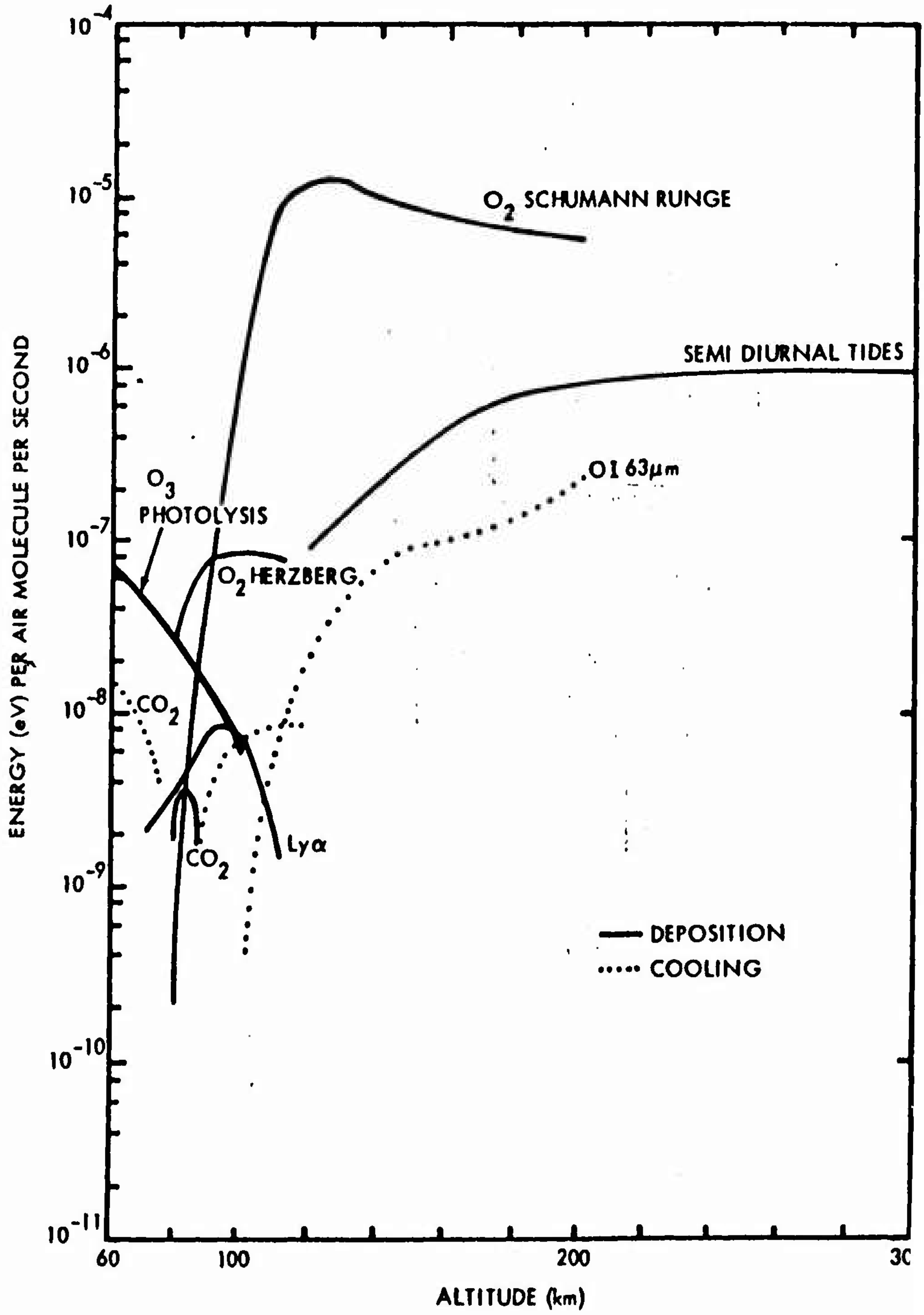

Figure A.3-9. Altitude dependence of energy absorption and emission. (Source: R-4, Figure 7)

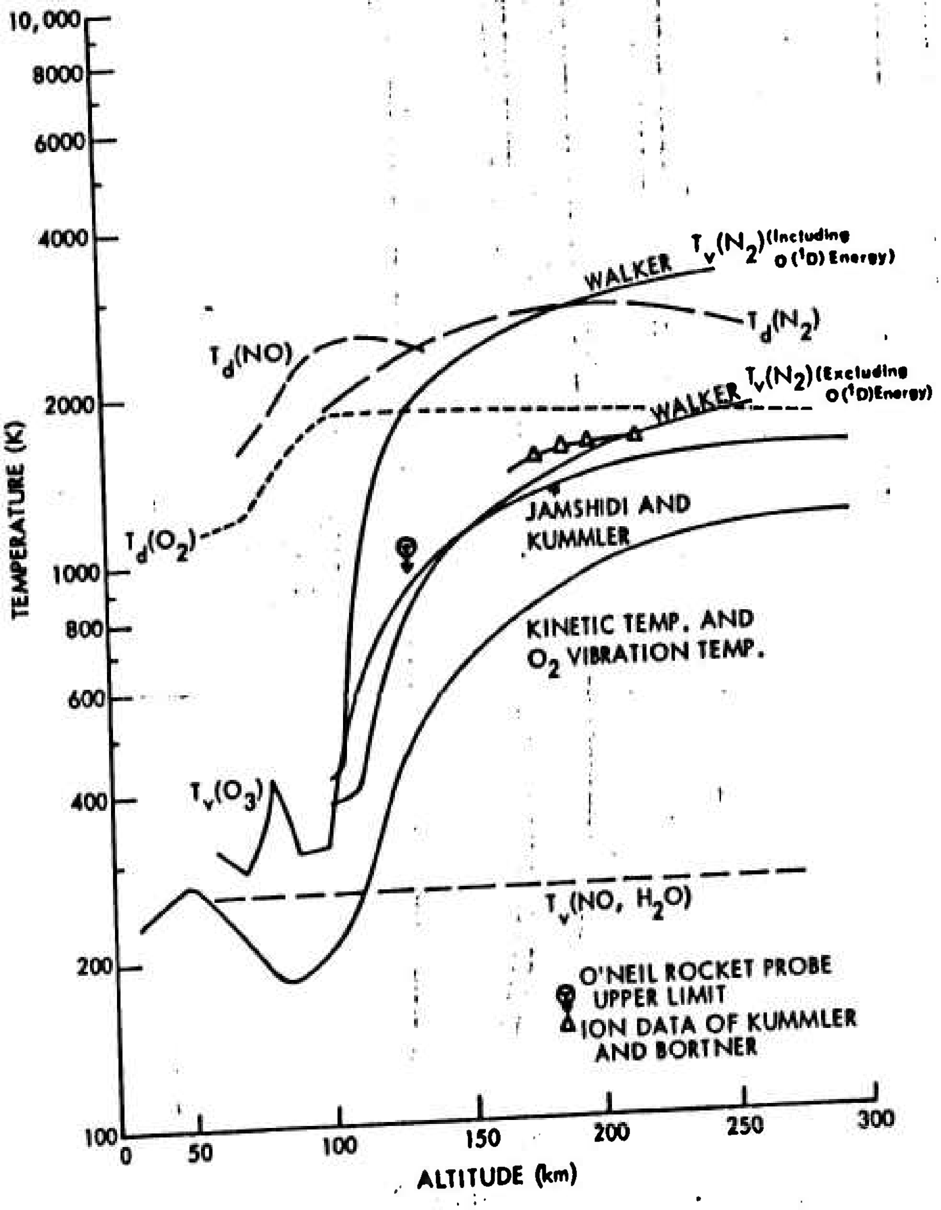

Figure A.3-10. Summary of vibrational temperatures in the normal atmosphere, compared to dissociation and kinetic temperatures. (Source: R-4, Figure 8)

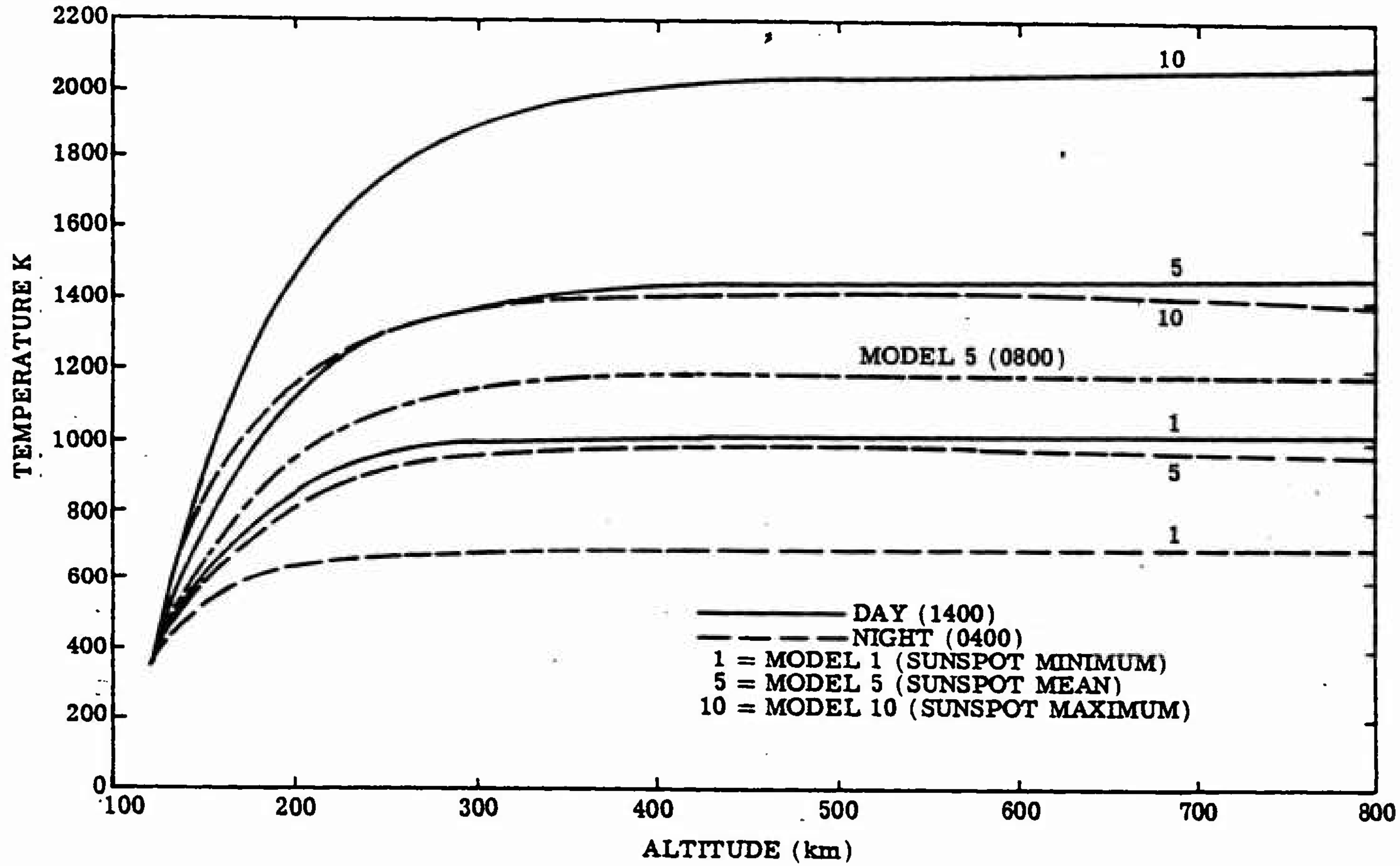

Figure A.3-11. Variation of atmospheric temperature with solar activity. (Source: E-8, Figure 2)

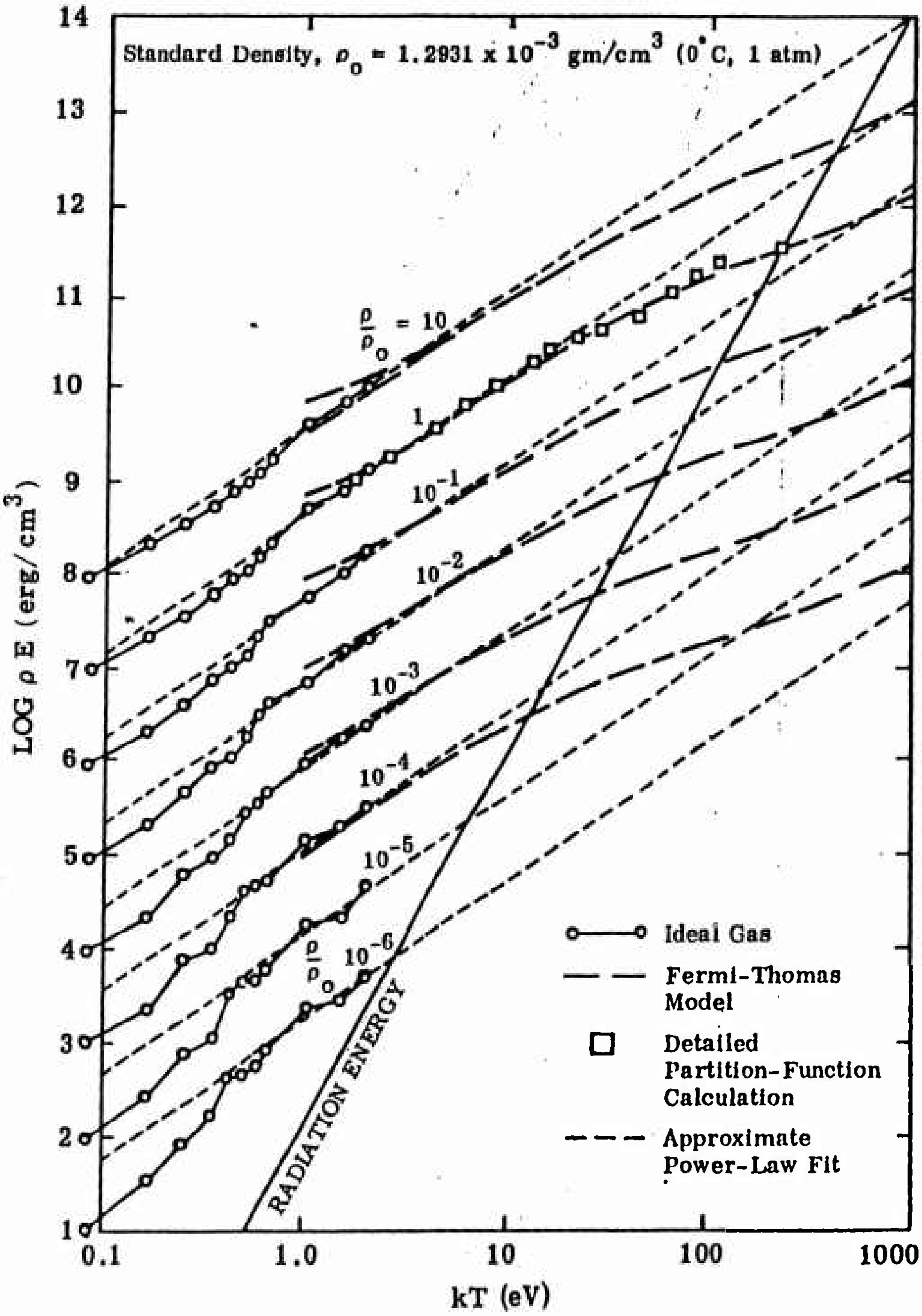

Figure A.3-12. Internal energy of air. (Source: E-8, Figure 15)

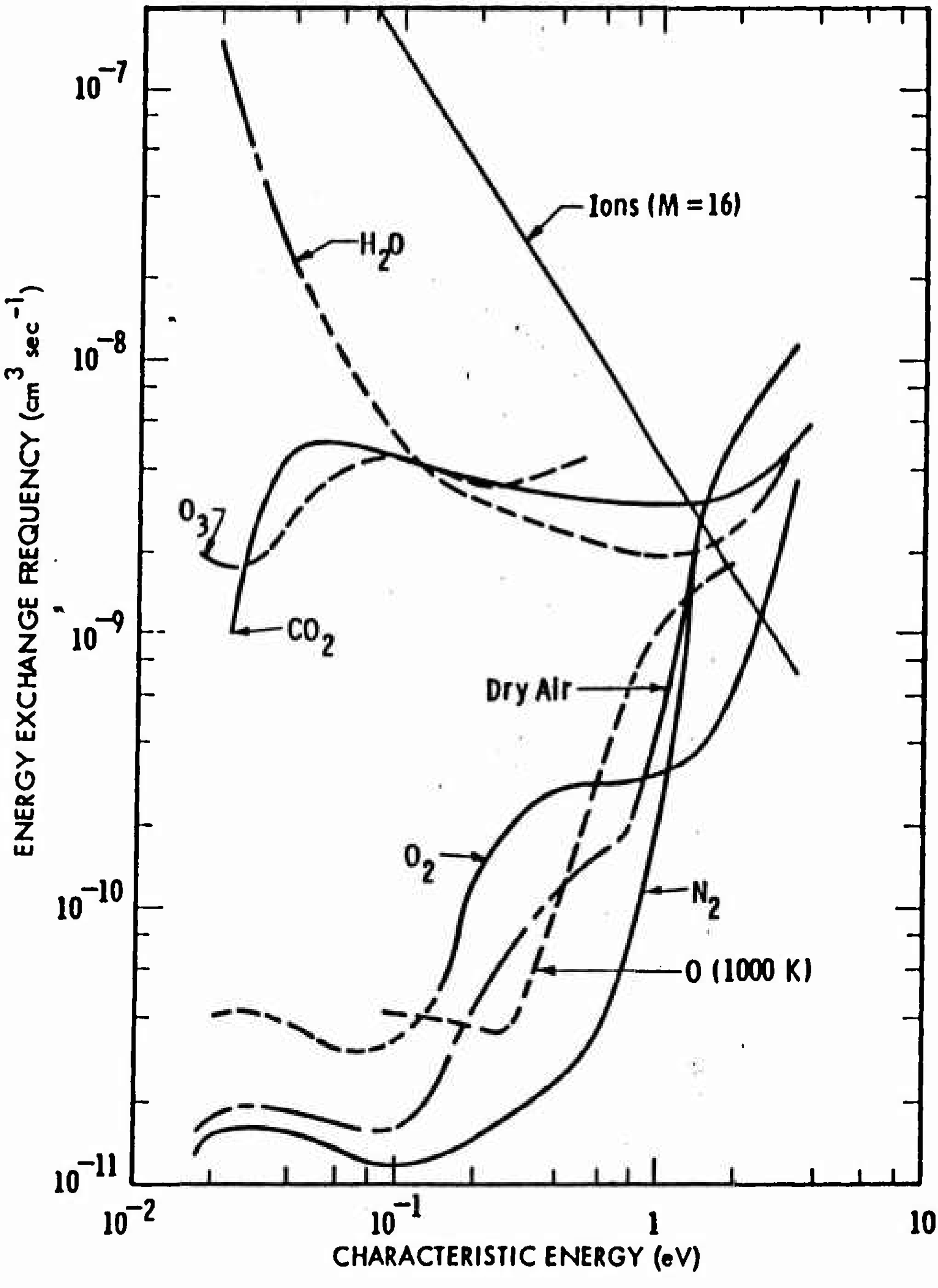

Figure A.3-13. Electron energy exchange frequencies for various atmospheric gases. (Source: R-21, Figure 3)

Table A.3-1. Electron energy exchange frequencies in atmospheric gases in cm^3 sec^{-1}. Gas temperature is 200 K except for atomic oxygen which is at 1000 K. (Source: R-21, Table 2)

ϵ_K	N_2	O_2	O	H_2O	CO_2	O_3	Dry Air	NO
1.72(-2)	1.2(-11)				1.4(-10)	2(-9)	9.4(-12)	1.6(-10)
2(-2)	1.5(-11)			1.5(-7)	5.1(-10)	1.8(-9)	1.2(-11)	1.4(-10)
3(-2)	1.6(-11)	8.0(-12)		4.4(-8)	3.2(-9)	1.9(-9)	1.25(-11)	1.03(-10)
5(-2)	1.4(-11)	1.1(-11)		1.45(-8)	4.9(-9)	3.5(-9)	1.1(-11)	9.6(-11)
7(-2)	1.25(-11)	1.7(-11)		8(-9)	4.8(-9)	4.2(-9)	1.1(-11)	7.9(-11)
1(-1)	1.17(-11)	2.6(-11)	4.1(-11)	5(-9)	4.4(-9)	4.4(-9)	1.25(-11)	7.0(-11)
1.5(-1)	1.28(-11)	5.3(-10)	3.9(-11)	3.6(-9)	3.9(-9)	3.9(-9)	2.5(-11)	1.4(-10)
2(-1)	1.47(-11)	1.25(-10)	3.6(-11)	3.1(-9)	3.7(-9)	3.5(-9)	4.5(-11)	6(-10)
3(-1)	1.86(-11)	2.15(-10)	4.5(-11)	2.7(-9)	3.4(-9)	3.9(-9)	8(-11)	2.6(-9)
5(-1)	4(-11)	2.8(-10)	2.0(-10)	2.3(-9)	3.1(-9)	5.4(-9)	1.4(-10)	3.8(-9)
7(-1)	5.5(-11)	2.9(-10)	5.0(-10)	2.0(-9)	3.0(-9)		1.7(-10)	3.4(-9)
1	1.9(-10)	3.1(-10)	1.0(-9)	1.9(-9)	3.0(-9)		4.7(-10)	3.0(-9)
1.5	3(-9)	4.1(-10)	1.5(-9)	2.1(-9)	3.1(-9)		2.6(-9)	7.5(-9)
2	5.5(-9)	7.2(-10)	1.8(-9)	2.5(-9)	3.4(-9)		5.5(-9)	1.3(-8)
3	1.0(-8)	2.6(-9)		4.3(-9)	4.7(-9)		1.07(-8)	1.8(-8)

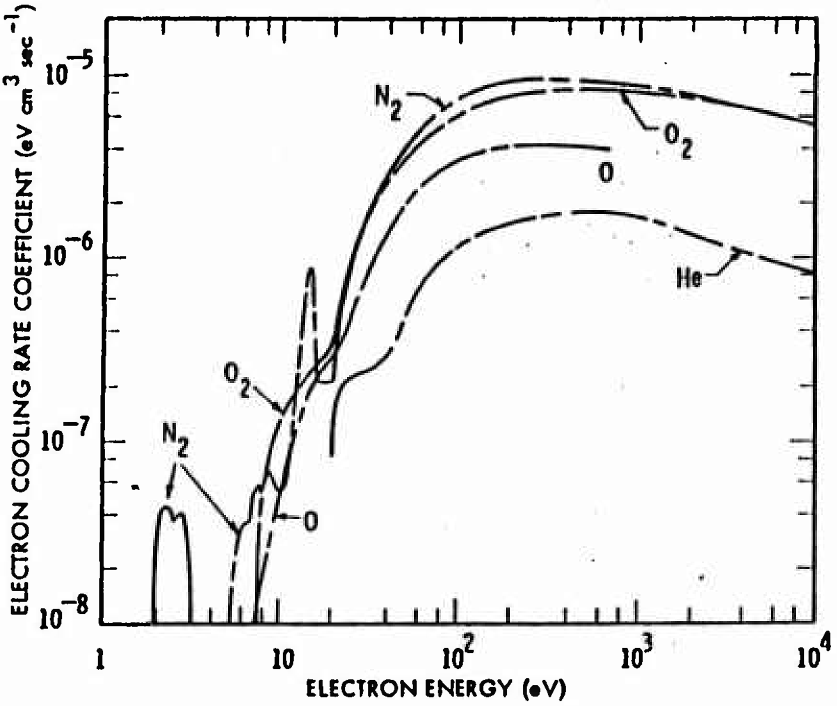

Figure A.3-14. Electron cooling rates in atmospheric gases. (Source: R-21, Figure 4)

Table A.3-2. Electron cooling rate coefficient in eV cm^3 sec^{-1}. (Source: R-21, Table 3)

ε (eV)	N_2	O_2	O	He
1(4)	5.3(-6)	5.4(-6)		8.2(-7)
5(3)	6.4(-6)	6.0(-6)		1.0(-6)
2(3)	8.0(-6)	7.4(-6)		1.3(-6)
1(3)	8.8(-6)	8.2(-6)		1.7(-6)
5(2)	9.3(-6)	8.0(-6)	4.0(-6)	1.6(-6)
2(2)	9.4(-6)	7.6(-6)	4.0(-6)	1.5(-6)
1(2)	7.6(-6)	6.5(-6)	3.6(-6)	1.2(-6)
5(1)	4.3(-6)	3.3(-6)	2.1(-6)	5.0(-7)
3(1)	1.6(-6)	1.8(-6)	8.1(-7)	2.4(-7)
2(1)	2.1(-7)	3.6(-6)	3.1(-7)	

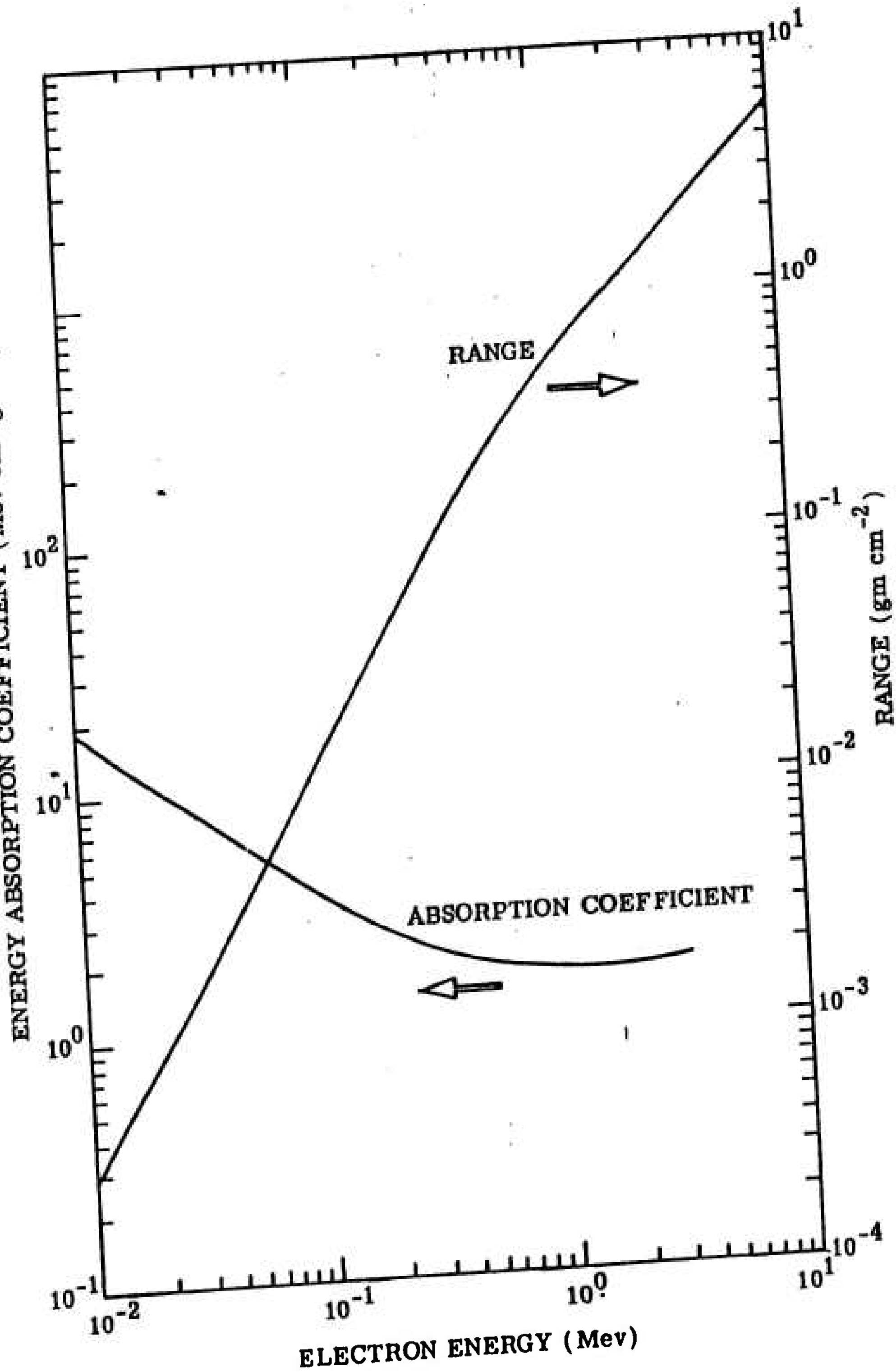

Figure A.3-15. Energy absorption coefficient and total range for an electron in air. (Source: E-2, Figure 29)

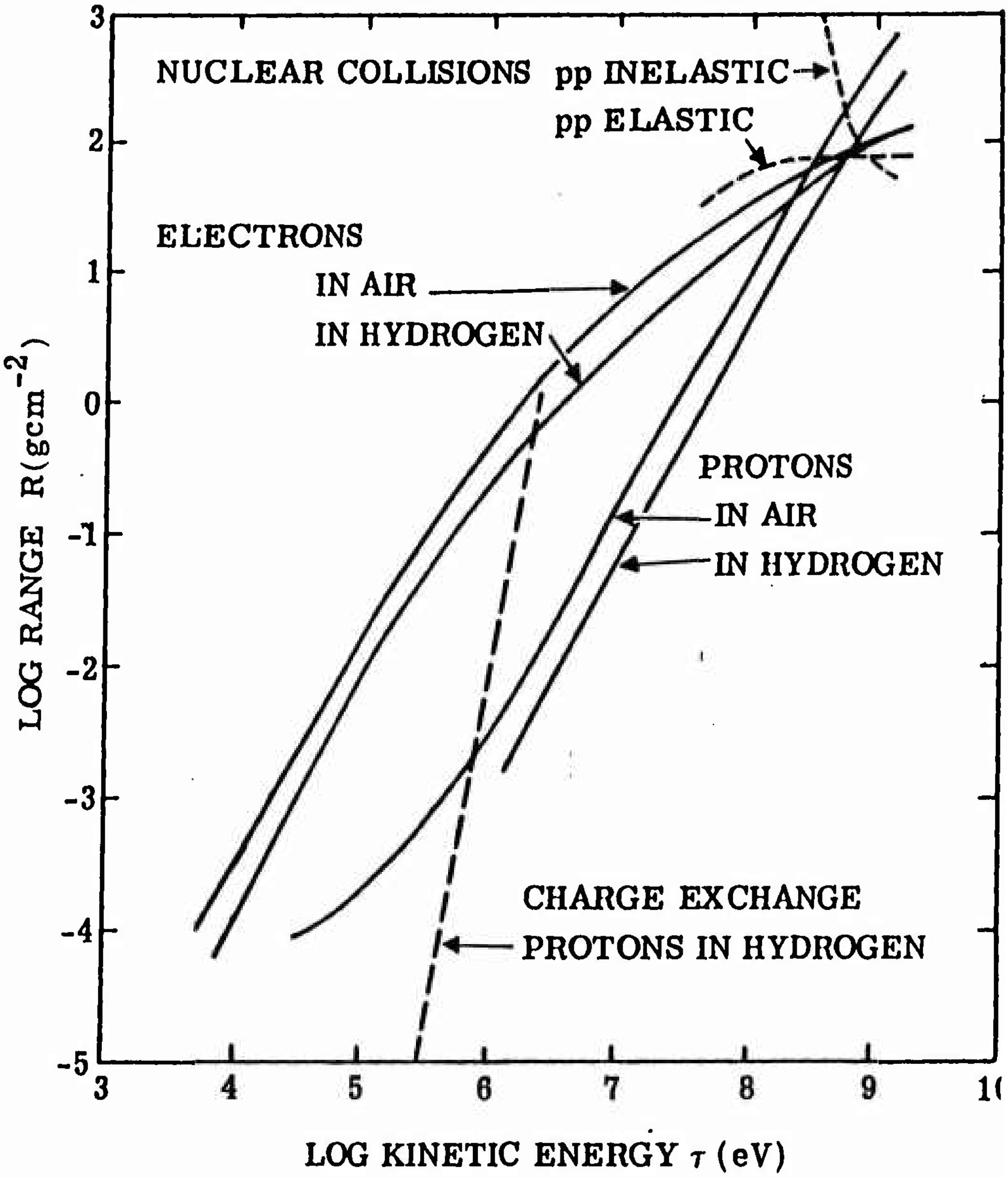

Figure A.3-16. Ranges of electrons and protons in the air. (Source: T-5, Figure 1)

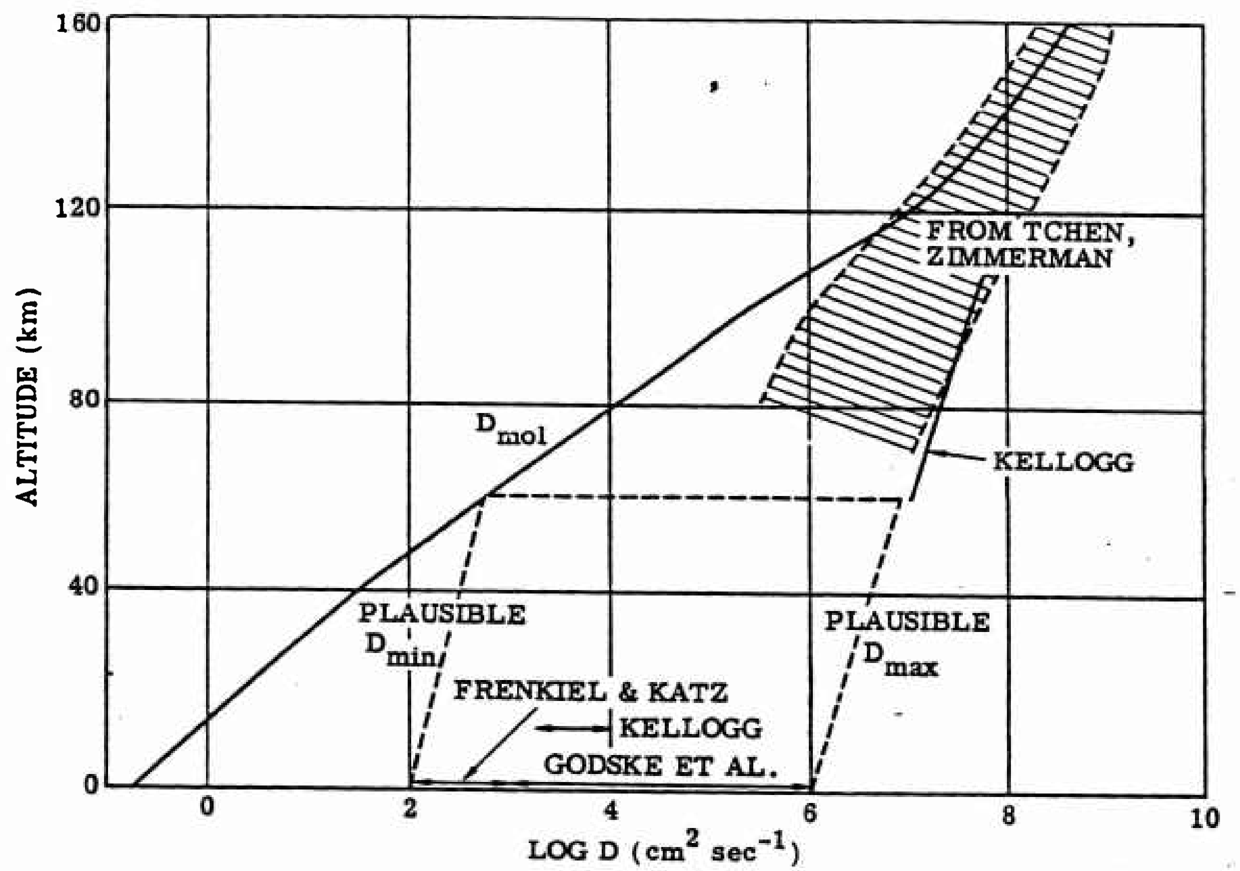

Figure A.4-1. Effective atmospheric diffusion coefficient D as a function of altitude. (Source: R-3, Figure 5)

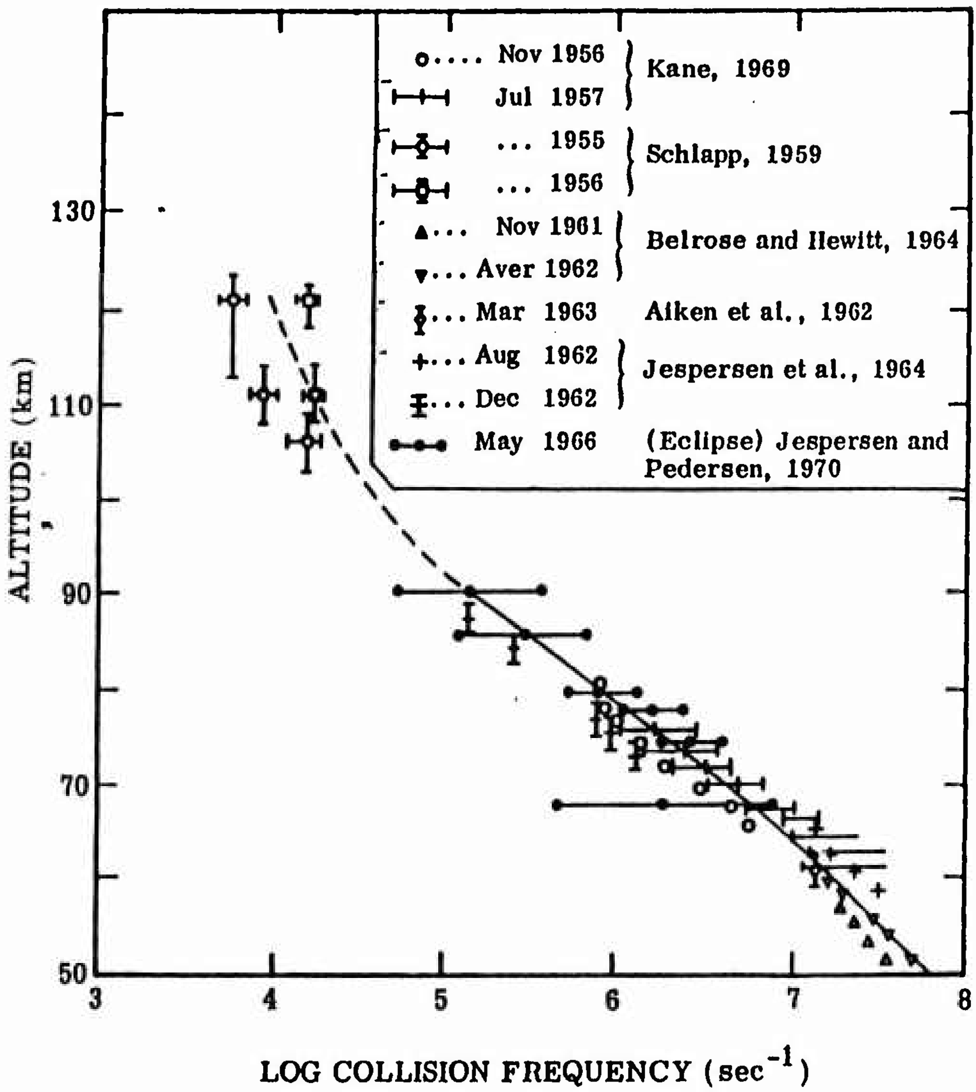

Figure A.4-2. Collision frequency measurements. (Source: R-9, Figure 3)

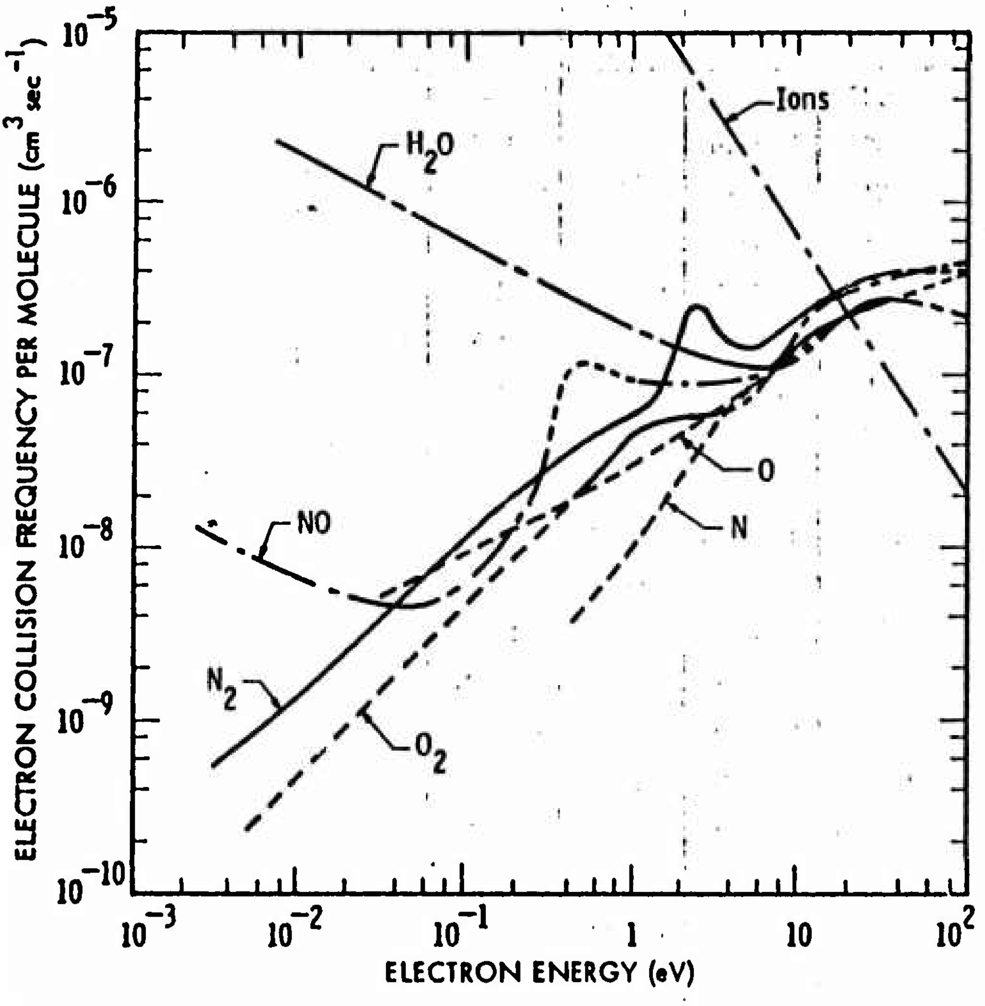

Figure A.4-3. Electron collision frequencies in various atmospheric gases. (Source: R-21, Figure 1)

Table A.4-1. Electron collision frequencies per molecule. (Source: R-21, Table 1)

ε (eV)	N_2	O_2	NO	O	N	H_2O
.005	7.5(-10)		9.7(-9)			2.85(-6)
.007	9.7(-10)		8.0(-9)			2.35(-6)
.01	1.3(-9)		6.7(-9)			1.93(-6)
.015	1.87(-9)		5.7(-9)			1.57(-6)
.02	2.43(-9)	1.2(-9)	5.25(-9)			1.36(-6)
.03	3.53(-9)	1.7(-9)	4.7(-9)	6.0(-9)		1.10(-6)
.05	5.65(-9)	2.8(-9)	4.6(-9)	7.2(-9)		8.5(-7)
.07	7.7(-9)	4.0(-9)	4.9(-9)	8.5(-9)		7.2(-7)
.1	1.10(-8)	5.0(-9)	5.9(-9)	1.02(-8)		6.0(-7)
.15	1.60(-8)	6.5(-9)	9.0(-9)	1.3(-8)		4.85(-7)
.2	2.08(-8)	8.6(-9)	1.4(-8)	1.5(-8)		4.15(-7)
.3	2.90(-8)	1.32(-8)	4.0(-8)	1.8(-8)		3.4(-7)
.5	4.15(-8)	2.16(-8)	1.2(-7)	2.4(-8)	4.3(-9)	2.63(-7)
.7	5.1(-8)	3.05(-8)	1.06(-7)	2.8(-8)	6.2(-9)	2.25(-7)
1.0	6.0(-8)	4.65(-8)	9.5(-8)	3.5(-8)	9.5(-9)	1.93(-7)
1.5	8.7(-8)	5.5(-8)	9.3(-8)	4.4(-8)	1.68(-8)	1.64(-7)
2.0	1.9(-7)	5.75(-8)	9.2(-8)	5.2(-8)	2.55(-8)	1.48(-7)
3	2.2(-7)	6.1(-8)	9.2(-8)	6.6(-8)	4.1(-8)	1.30(-7)
5	1.46(-7)	7.3(-8)	9.6(-8)	9.3(-8)	8.0(-8)	1.17(-7)
7	1.64(-7)	1.02(-7)	1.1(-7)	1.17(-7)	1.03(-7)	1.13(-7)
10	2.08(-7)	1.48(-7)	1.77(-7)	1.52(-7)	1.3(-7)	1.24(-7)
15	2.75(-7)	1.93(-7)	2.6(-7)	2.1(-7)	1.55(-7)	1.74(-7)
20	3.15(-7)	2.2(-7)	1.95(-7)			2.27(-7)
30	3.6(-7)	2.6(-7)	3.4(-7)			2.70(-7)

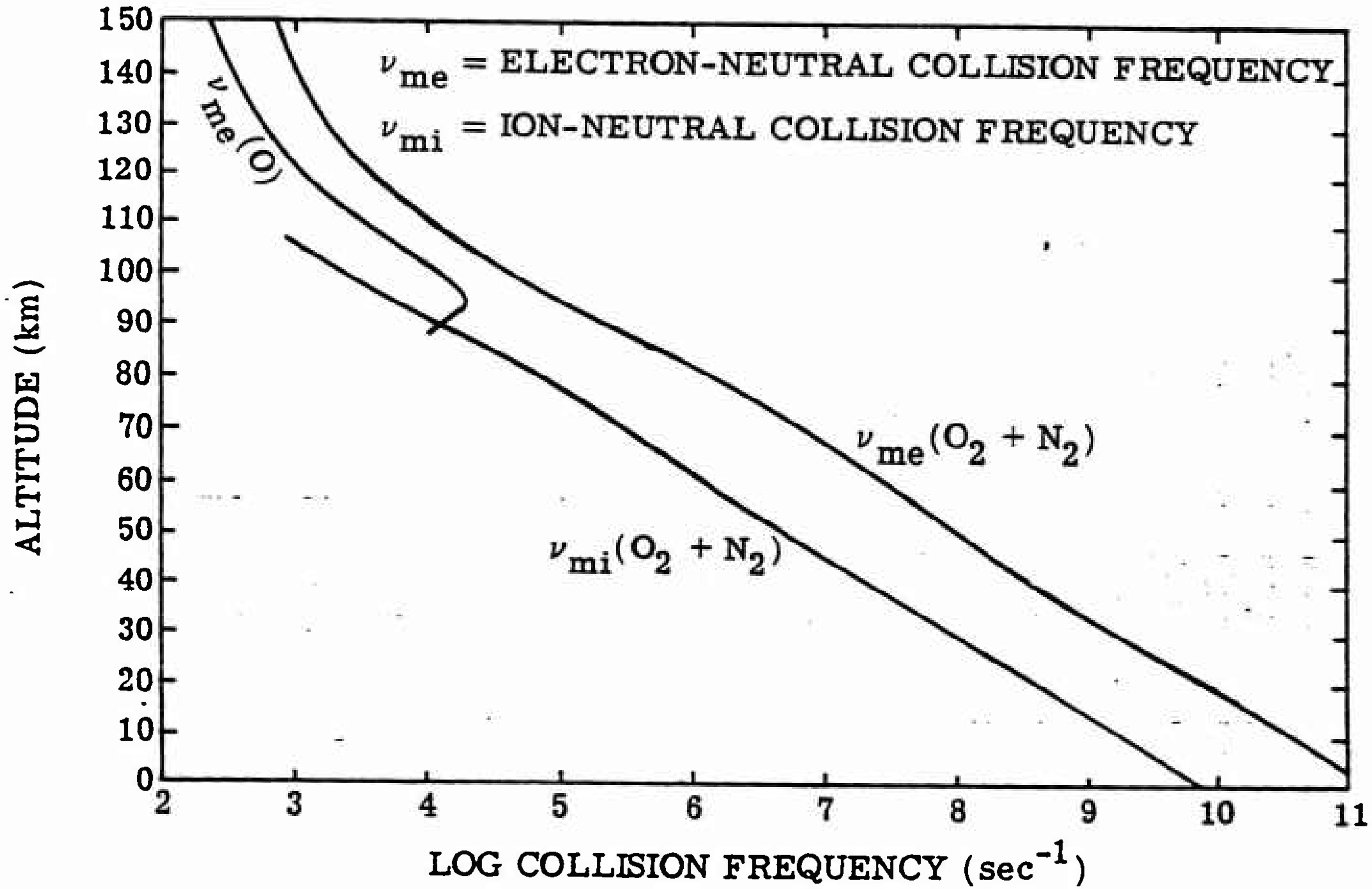

Figure A.4-4. Electron-neutral and ion-neutral collision frequencies. (Source: E-5, Figure 1)

Table A.4-2. Mobilities of ions in atmospheric gases. Values are in units of 10^{19} V^{-1} cm^{-1} sec^{-1}. (Source: R-21, Table 4)

Ion	GAS			
	N_2	O_2	Air	O
N^+	(8.8) 8.0	(9.4)	8.2	(14.4)
N_2^+	5.0	(7.6) 8.6	5.4	(12.5)
N_3^+	(6.6) 6.1	(6.9)	6.2	(11.5)
N_4^+	(6.2) 6.3	(6.5)	6.3	(11.1)
O^+	(8.4) 8.6-10.0	(9.0) 8.9	(8.5) 9.0	14.4
O_2^+	(7.0) 8.2	6.0	6.7	14.5
O_4^+	(6.1)	(6.4)	(6.1)	(11.0)
NO^+	(7.1) 9.0	(7.6)	9.4	14.8
H_3O^+	(8.0)	(8.5)	(8.1)	(13.3)
$H_3O^+ \cdot H_2O$	(6.8)	(7.1)	(6.8)	(11.8)
O_2^-	(7.0)	5.8	6.7	(12.0)
O_3^-	(6.4)	(6.7) 6.9	(6.4)	(11.5)
O_4^-	(6.1)	(6.4) 5.8	6.0	(11.0)
CO_3^-	(6.3)	(6.4) 6.7	(6.3)	(11.0)
CO_4^-	(5.9)	(6.2) 6.6	(6.0)	10 10.8
NO_2^-	(6.4)	(6.7)	(6.5)	(11.4)
NO_3^-	(6.1)	(6.4)	(6.2)	(11.0)
$NO_3^- \cdot H_2O$	(5.9)	(6.1)	(6.0)	(11.8)

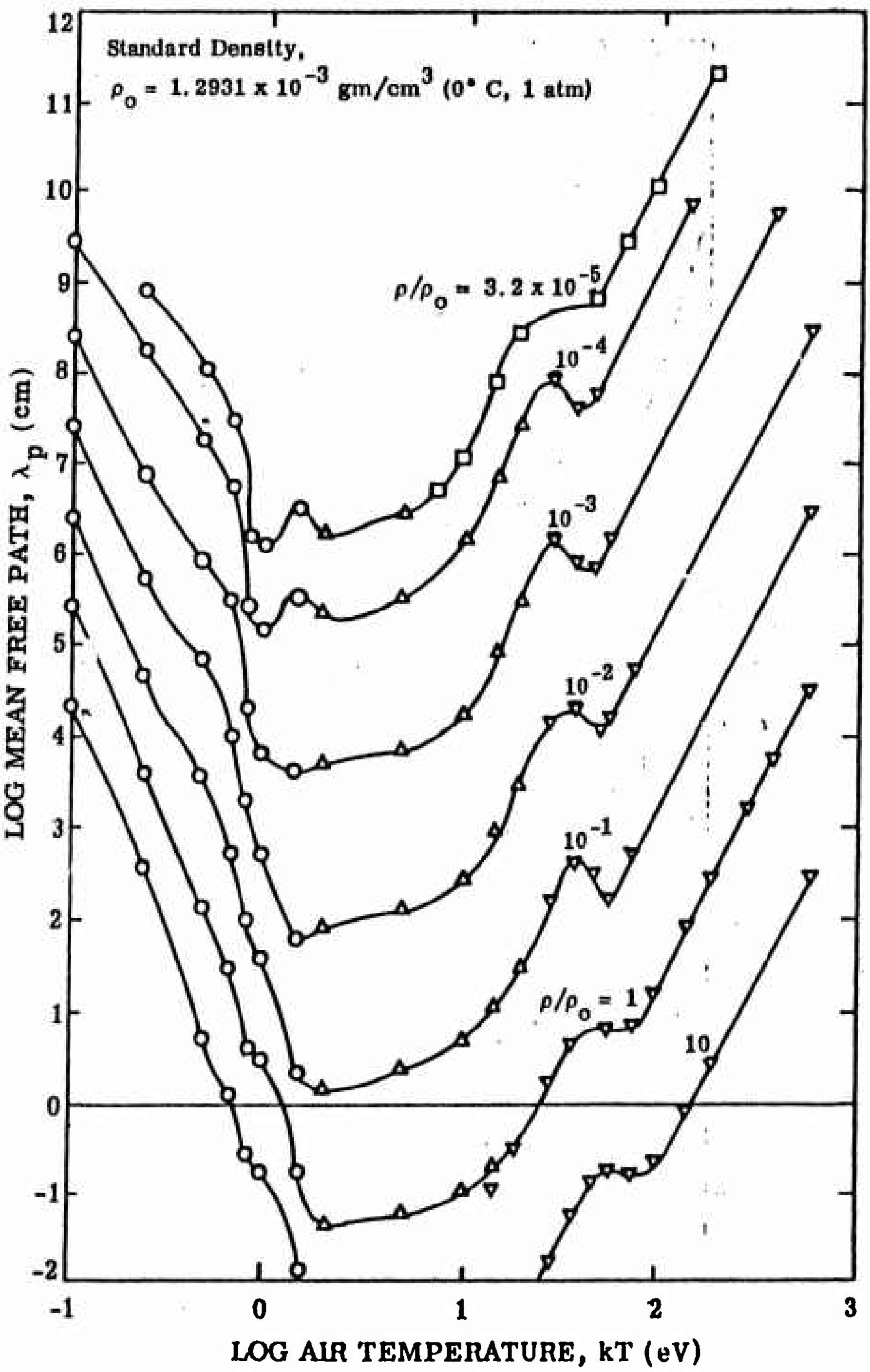

Figure A.4-5. Planck mean free path (values shown assume chemical equilibrium, neglecting atomic lines). (Source: E-8, Figure 17)

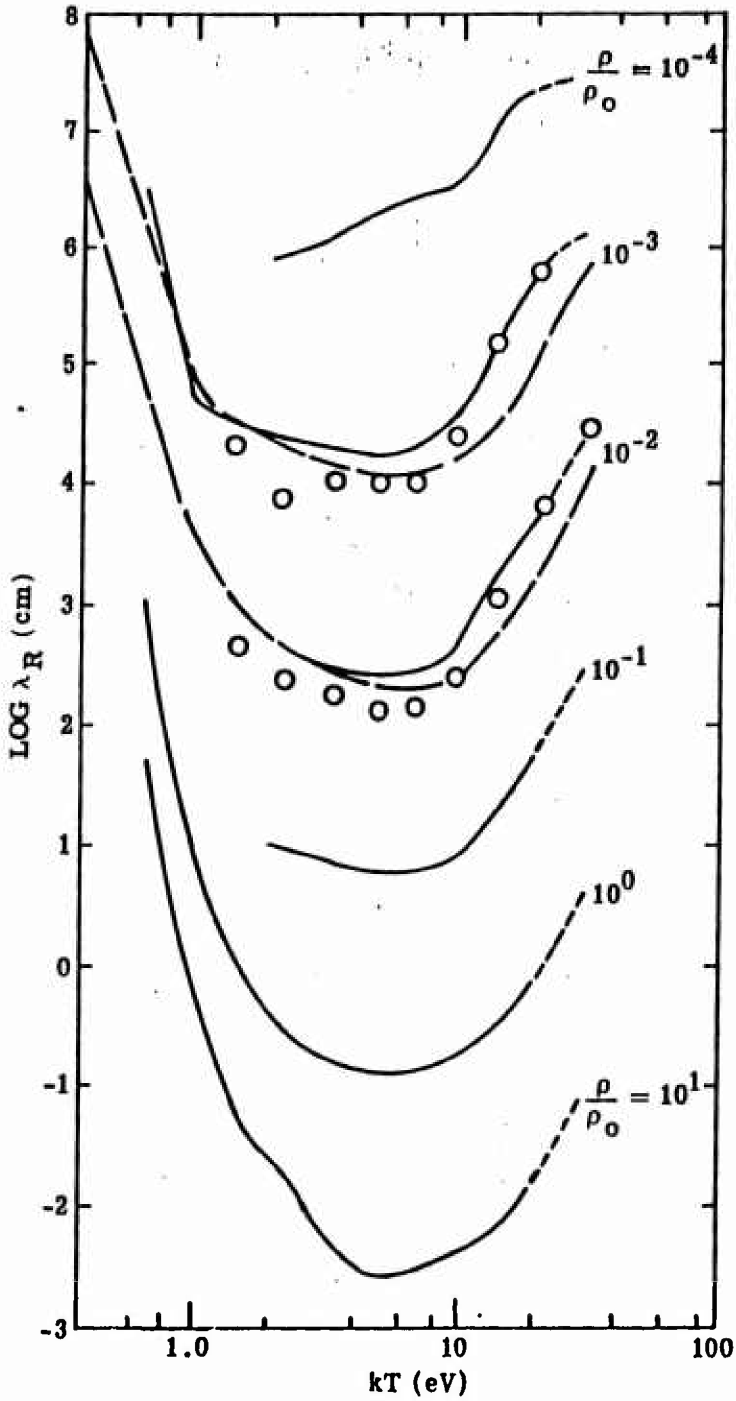

Figure A.4-6. Rosseland mean free path λ_R in air. (Source: E-8, Figure 18)

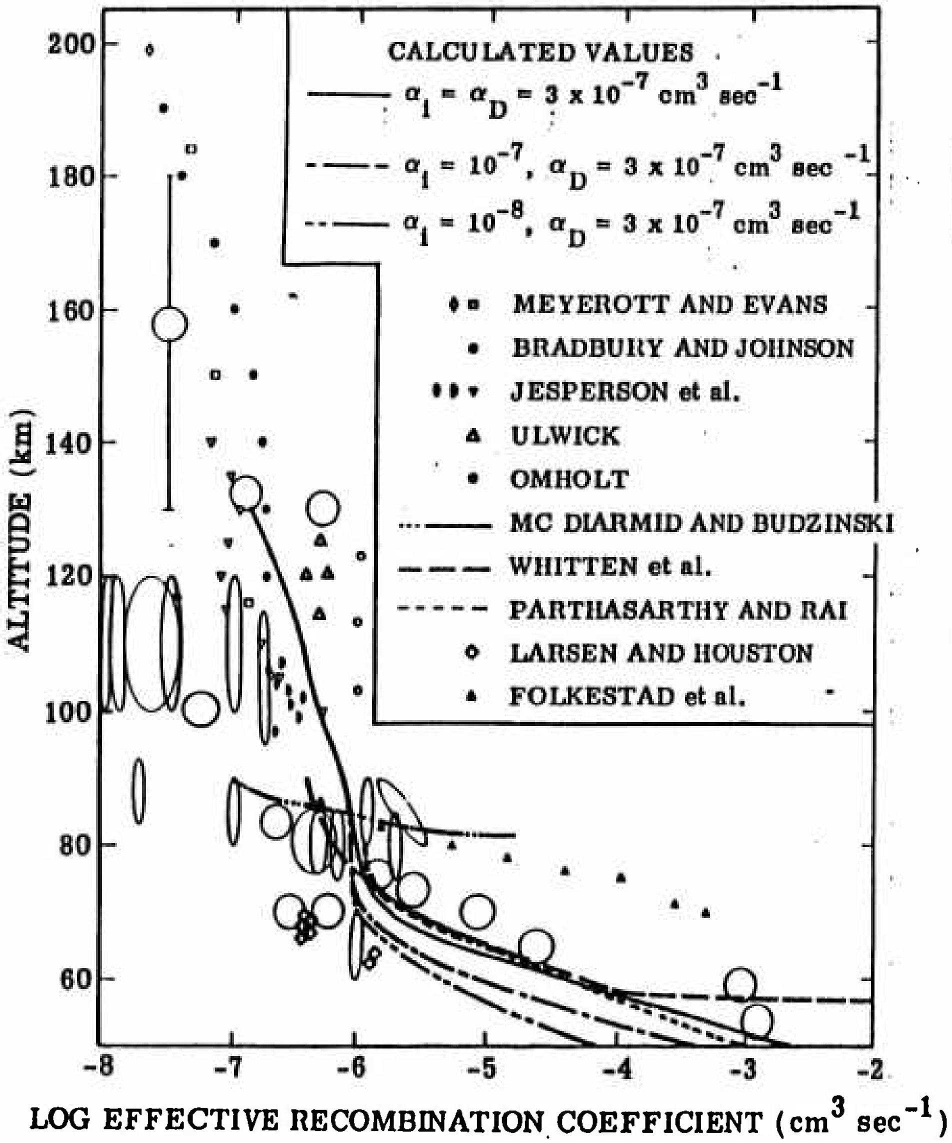

Figure A. 5-1. Effective recombination rate coefficients measured in the upper atmosphere. Wide ovals indicate a range of values for α_{eff} and for altitude. Narrow ovals or bars indicate an altitude range. E-region values are plotted at 110 km. (Source: R-9, Figure 2)

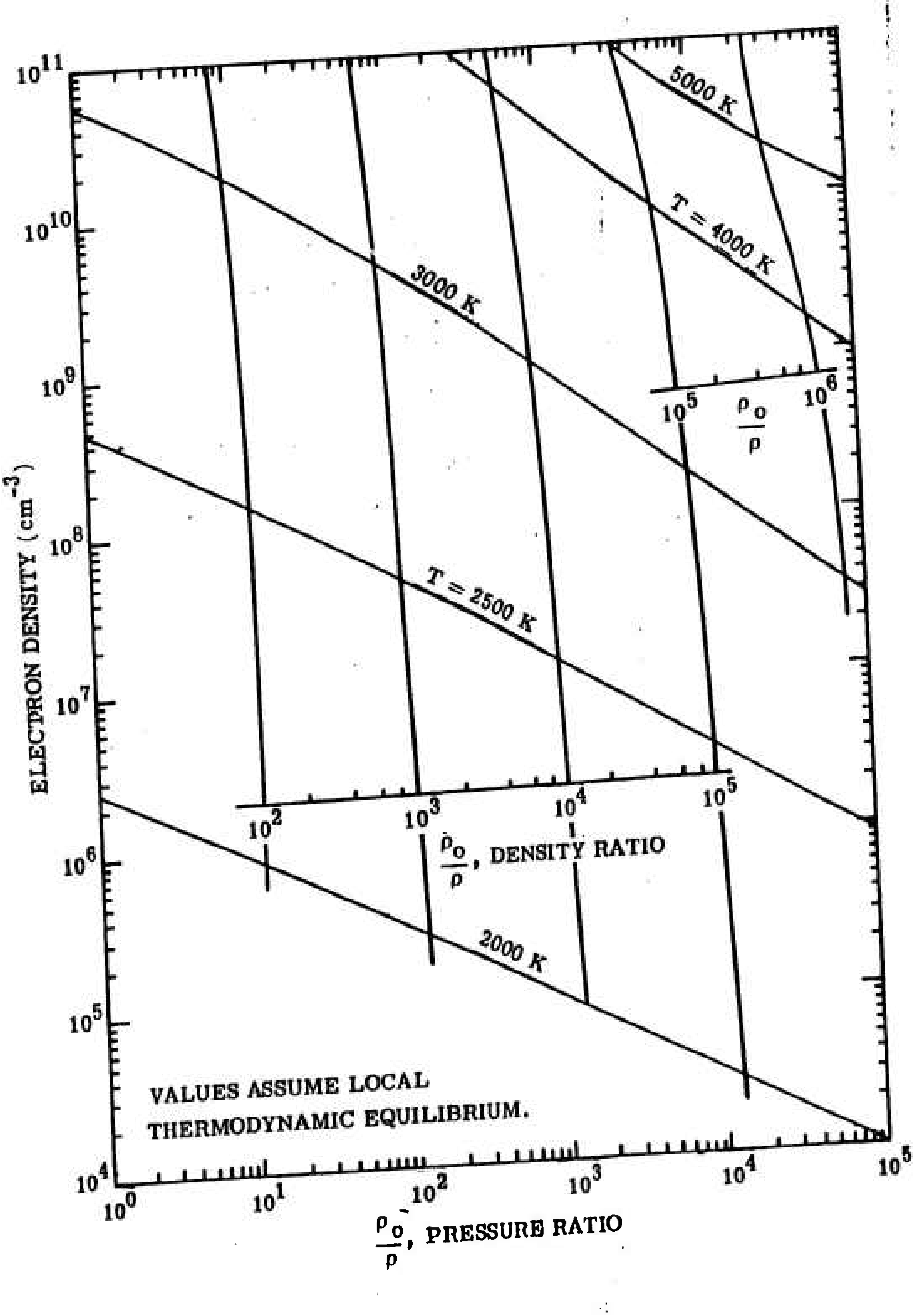

Figure A.5-2. Electron density due to thermal ionization. (Source: E-2, Figure 15)

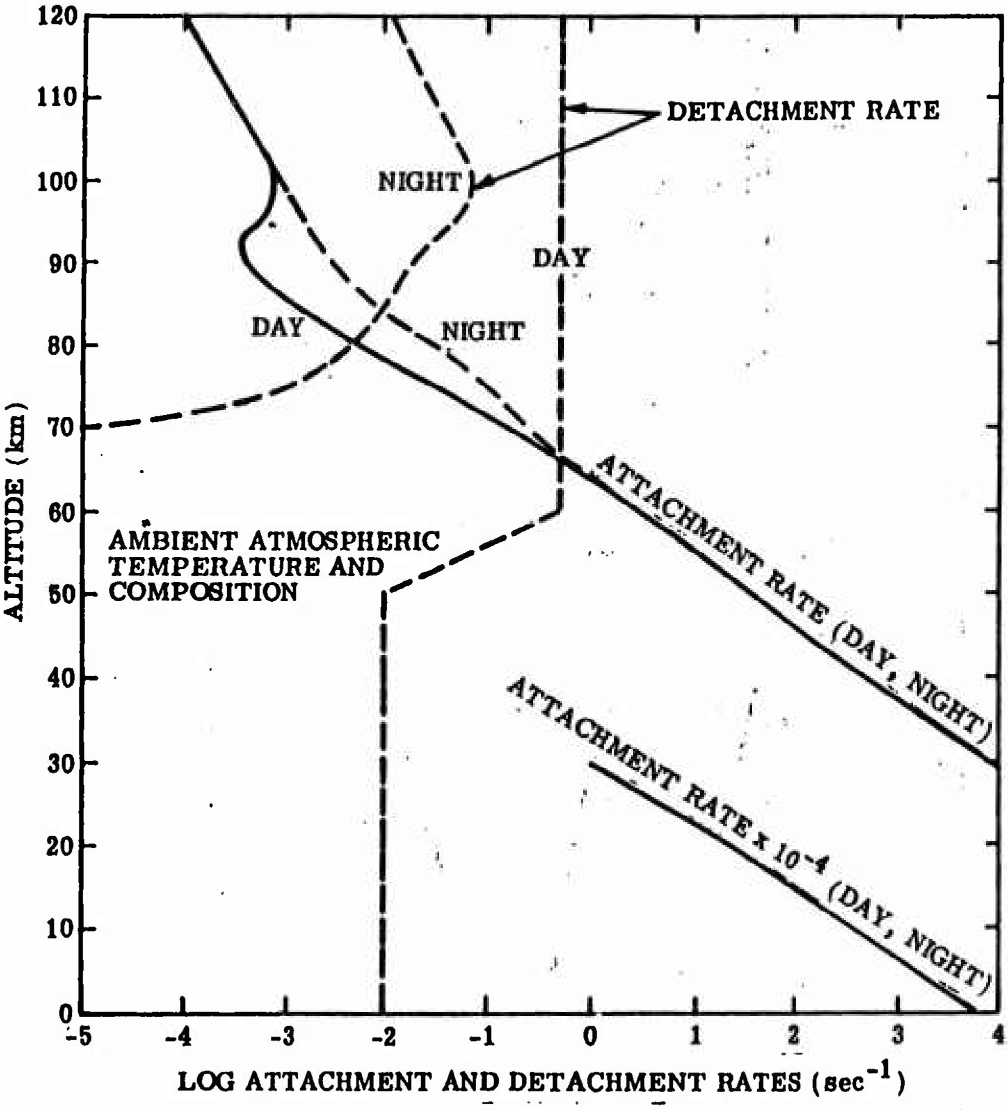

Figure A. 5-3. Attachment and detachment rates versus altitude. (Source: E-3, Figure 1)

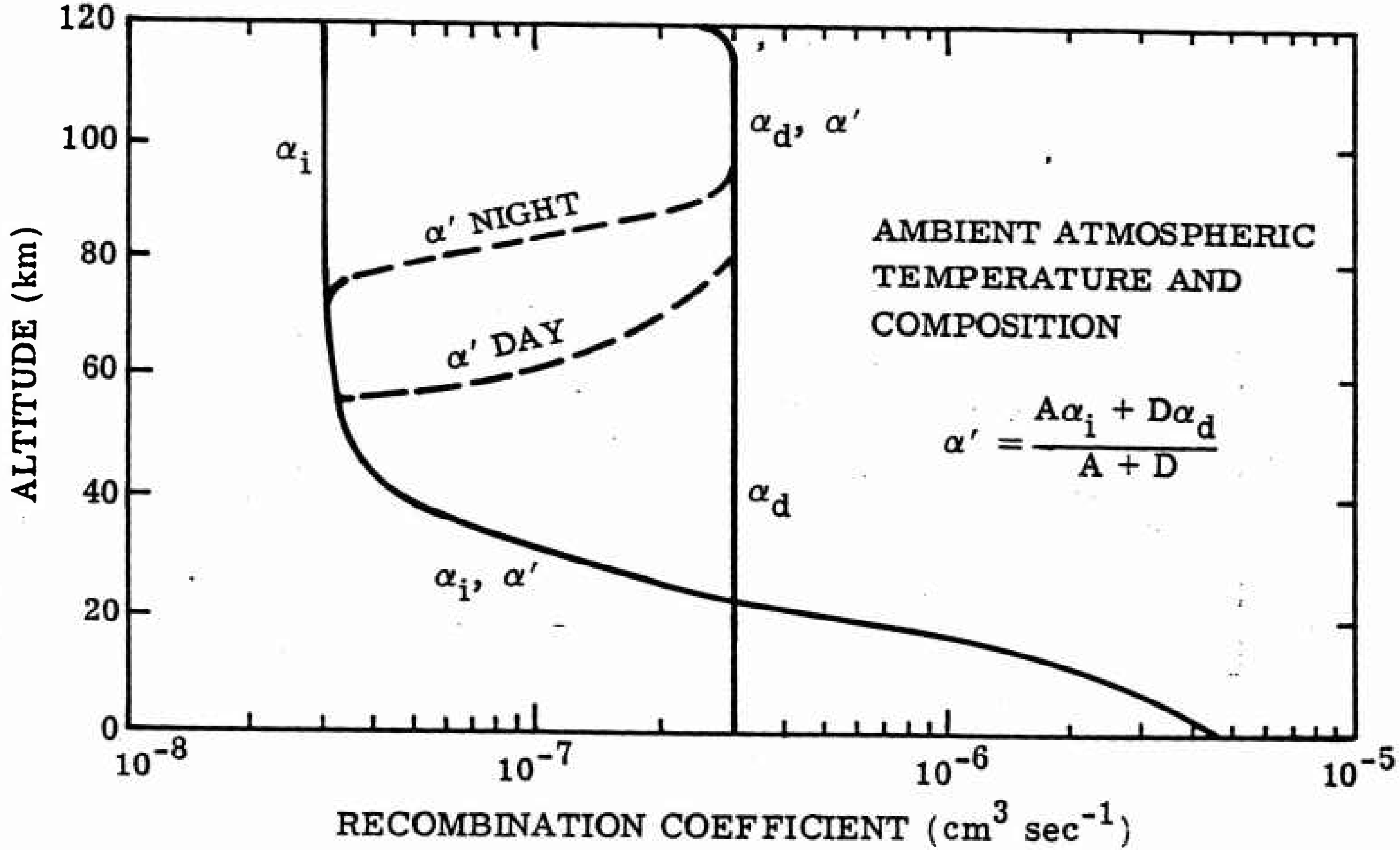

Figure A.5-4. Recombination rate coefficients versus altitude. (Source: E-3, Figure 2)

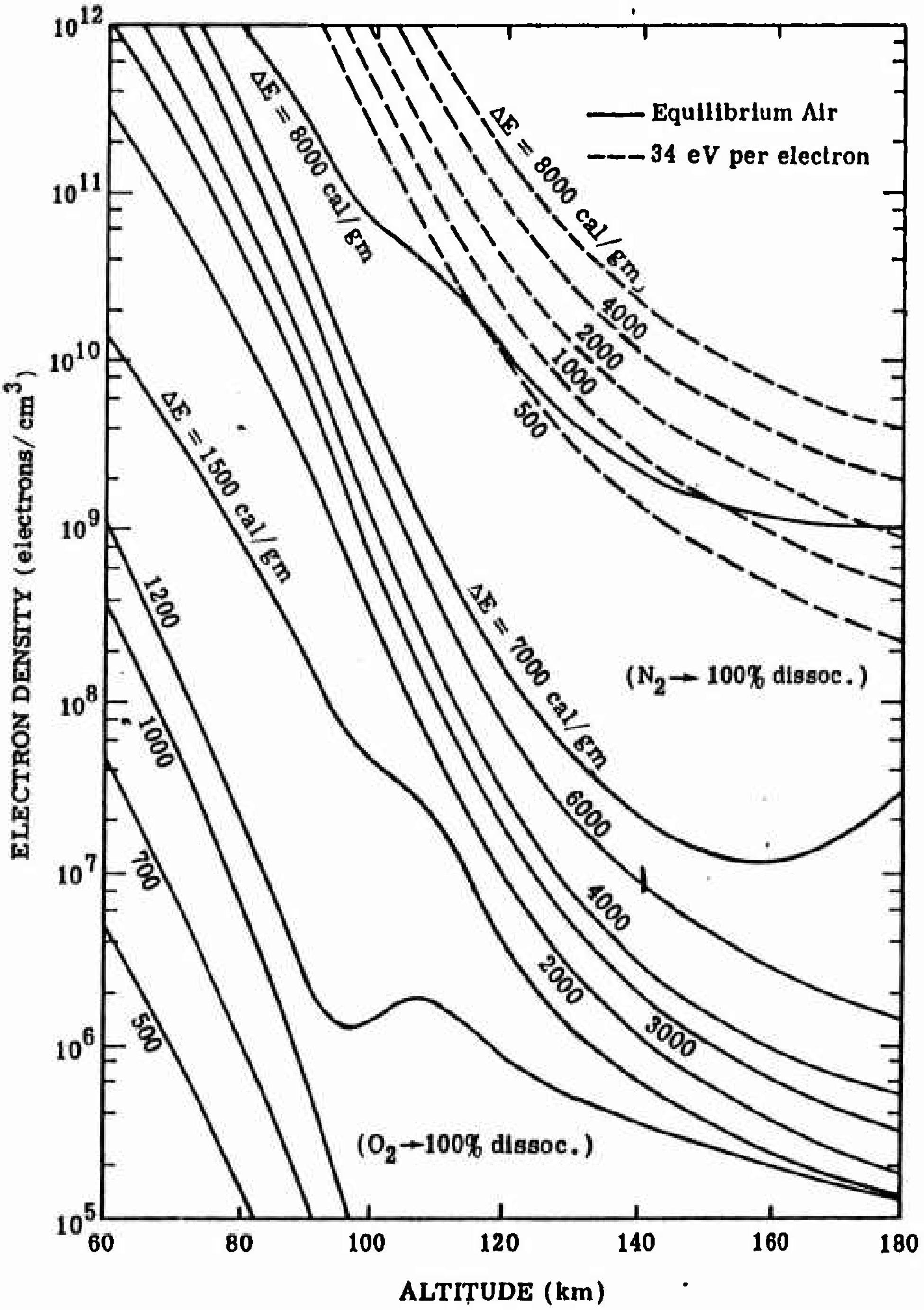

Figure A.5-5. Ionization produced by energy deposition, based on U.S. standard atmosphere, 1962. (Source: E-8, Figure 16)

SECTION B

CHEMICAL REACTIVITY DATA

B

Table B.1-1. Periodic Table of the Elements. (Source: Handbook of Chemistry and Physics, 54th Edition)

KEY TO CHART: Atomic Number — 50; Symbol — Sn; Atomic Weight — 118.69; Oxidation States — +2 +4; Electron Configuration — -18-18-4

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0	Orbit
1 H +1 -1 1.0080 1																	2 He 0 4.00260 2	K
3 Li +1 6.94$_1$ 2-1	4 Be +2 9.01218 2-2											5 B +3 10.81 2-3	6 C +2 +4 -4 12.011 2-4	7 N +1 +2 +3 +4 +5 -1 -2 -3 14.0067 2-5	8 O -2 15.9994 2-6	9 F -1 18.99840 2-7	10 Ne 0 20.17$_9$ 2-8	K-L
11 Na +1 22.98977 2-8-1	12 Mg +2 24.305 2-8-2	Transition Elements					Group 8			Transition Elements		13 Al +3 26.9815 2-8-3	14 Si +2 +4 -4 28.086 2-8-4	15 P +3 +5 -3 30.9738 2-8-5	16 S +4 +6 -2 32.06 2-8-6	17 Cl +1 +5 +7 -1 35.453 2-8-7	18 Ar 0 39.948 2-8-8	K-L-M
19 K +1 39.10$_2$ -8-8-1	20 Ca +2 40.08 -8-8-2	21 Sc +3 44.9559 -8-9-2	22 Ti +2 +3 +4 47.90 -8-10-2	23 V +2 +3 +4 +5 50.941$_4$ -8-11-2	24 Cr +2 +3 +6 51.996 -8-13-1	25 Mn +2 +3 +4 +7 54.9380 -8-13-2	26 Fe +2 +3 55.847 -8-14-2	27 Co +2 +3 58.9332 -8-15-2	28 Ni +2 +3 58.71 -8-16-2	29 Cu +1 +2 63.546 -8-18-1	30 Zn +2 65.38 -8-18-2	31 Ga +3 69.72 -8-18-3	32 Ge +2 +4 72.59 -8-18-4	33 As +3 +5 -3 74.9216 -8-18-5	34 Se +4 +6 -2 78.96 -8-18-6	35 Br +1 +5 -1 79.904 -8-18-7	36 Kr 0 83.80 -8-18-8	-L-M-N
37 Rb +1 85.467$_8$ -18-8-1	38 Sr +2 87.62 -18-8-2	39 Y +3 88.9059 -18-9-2	40 Zr +4 91.22 -18-10-2	41 Nb +3 +5 92.9064 -18-12-1	42 Mo +6 95.94 -18-13-1	43 Tc +4 +6 +7 98.9062 -18-13-2	44 Ru +3 101.07 -18-15-1	45 Rh +3 102.9055 -18-16-1	46 Pd +2 +4 106.4 -18-18-0	47 Ag +1 107.868 -18-18-1	48 Cd +2 112.40 -18-18-2	49 In +3 114.82 -18-18-3	50 Sn +2 +4 118.69 -18-18-4	51 Sb +3 +5 -3 121.75 -18-18-5	52 Te +4 +6 -2 127.60 -18-18-6	53 I +1 +5 +7 -1 126.9045 -18-18-7	54 Xe 0 131.30 -18-18-8	-M-N-O
55 Cs +1 132.9055 -18-8-1	56 Ba +2 137.34 -18-8-2	57* La +3 138.9055 -18-9-2	72 Hf +4 178.49 -32-10-2	73 Ta +5 180.947$_9$ -32-11-2	74 W +6 183.85 -32-12-2	75 Re +4 +6 +7 186.2 -32-13-2	76 Os +3 +4 190.2 -32-14-2	77 Ir +3 +4 192.22 -32-15-2	78 Pt +2 +4 195.09 -32-16-2	79 Au +1 +3 196.9665 -32-18-1	80 Hg +1 +2 200.59 -32-18-2	81 Tl +1 +3 204.37 -32-18-3	82 Pb +2 +4 207.2 -32-18-4	83 Bi +3 +5 208.9806 -32-18-5	84 Po +2 +4 (209) -32-18-6	85 At (210) -32-18-7	86 Rn 0 (222) -32-18-8	-N-O-P
87 Fr +1 (223) -18-8-1	88 Ra +2 (226) -18-8-2	89** Ac +3 (227) -18-9-2	104 — -32-10-2	105 —														-O-P-Q

* Lanthanides	58 Ce +3 +4 140.12 -20-8-2	59 Pr +3 140.9077 -21-8-2	60 Nd +3 144.24 -22-8-2	61 Pm +3 (145) -23-8-2	62 Sm +2 +3 150.4 -24-8-2	63 Eu +2 +3 151.96 -25-8-2	64 Gd +3 157.25 -25-9-2	65 Tb +3 158.9254 -27-8-2	66 Dy +3 162.50 -28-8-2	67 Ho +3 164.9303 -29-8-2	68 Er +3 167.26 -30-8-2	69 Tm +3 168.9342 -31-8-2	70 Yb +2 +3 173.04 -32-8-2	71 Lu +3 174.97 -32-9-2	-N-O-P
** Actinides	90 Th +4 232.0381 -18-10-2	91 Pa +5 +4 231.0359 -20-9-2	92 U +3 +4 +5 +6 238.029 -21-9-2	93 Np +3 +4 +5 +6 237.0482 -22-9-2	94 Pu +3 +4 +5 +6 (244) -24-8-2	95 Am +3 +4 +5 +6 (243) -25-8-2	96 Cm +3 (247) -25-9-2	97 Bk +3 +4 (247) -27-8-2	98 Cf +3 (251) -28-8-2	99 Es (254) -29-8-2	100 Fm (257) -30-8-2	101 Md (256) -31-8-2	102 No (254) -32-8-2	103 Lr -32-9-2	-O-P-Q

Numbers in parentheses are mass numbers of most stable isotope of that element.

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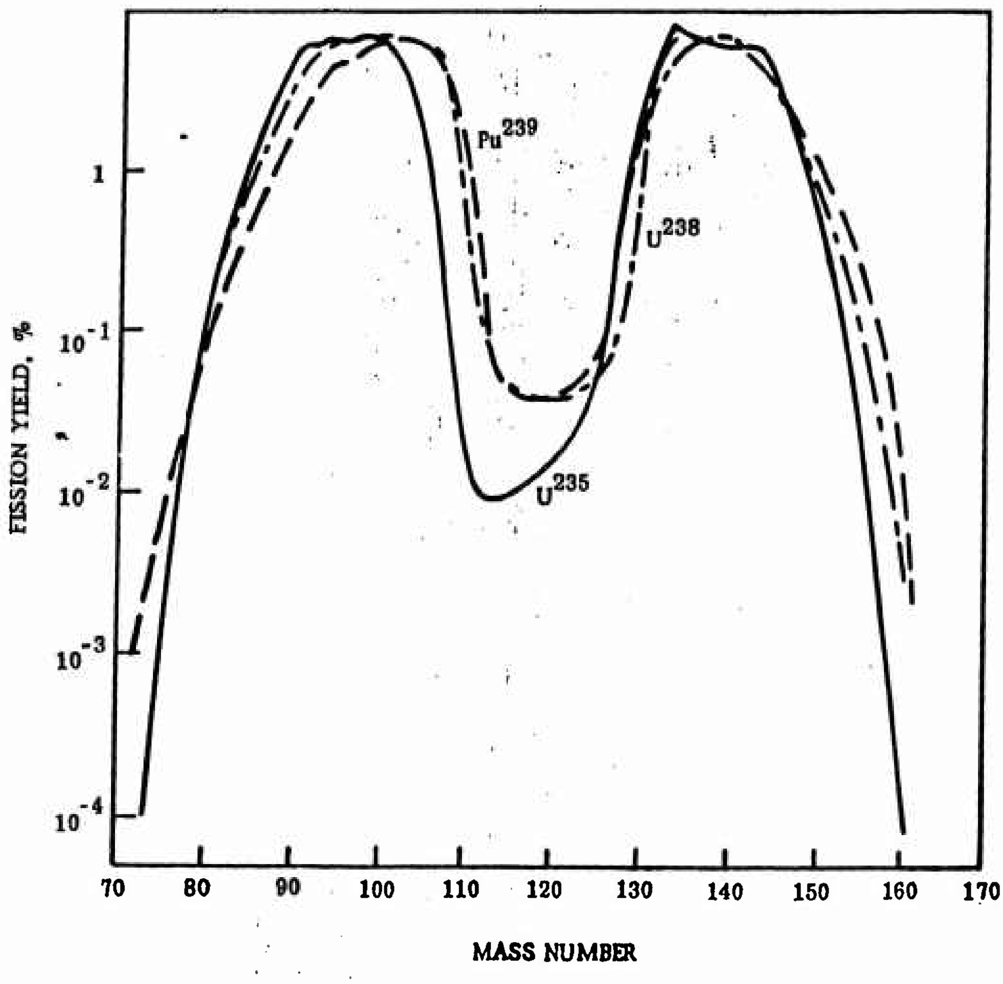

Figure B.1-1. Mass distribution for fission of U^{235}, U^{238}, and Pu^{239}. (Source: T-11, Figure 1)

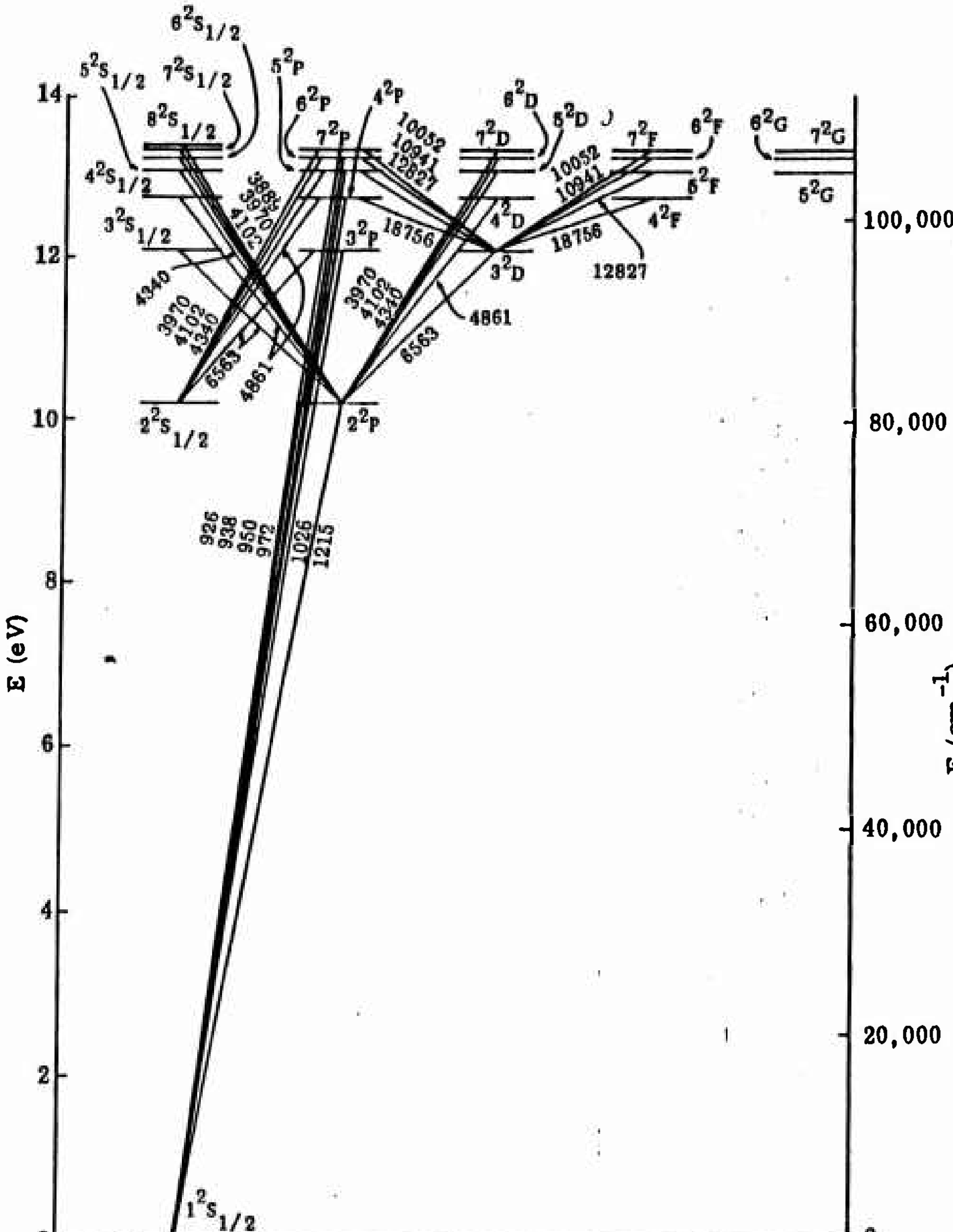

Figure B.2-1. Partial Grotrian diagram of hydrogen atom. (Source: R-10, Figure 1)

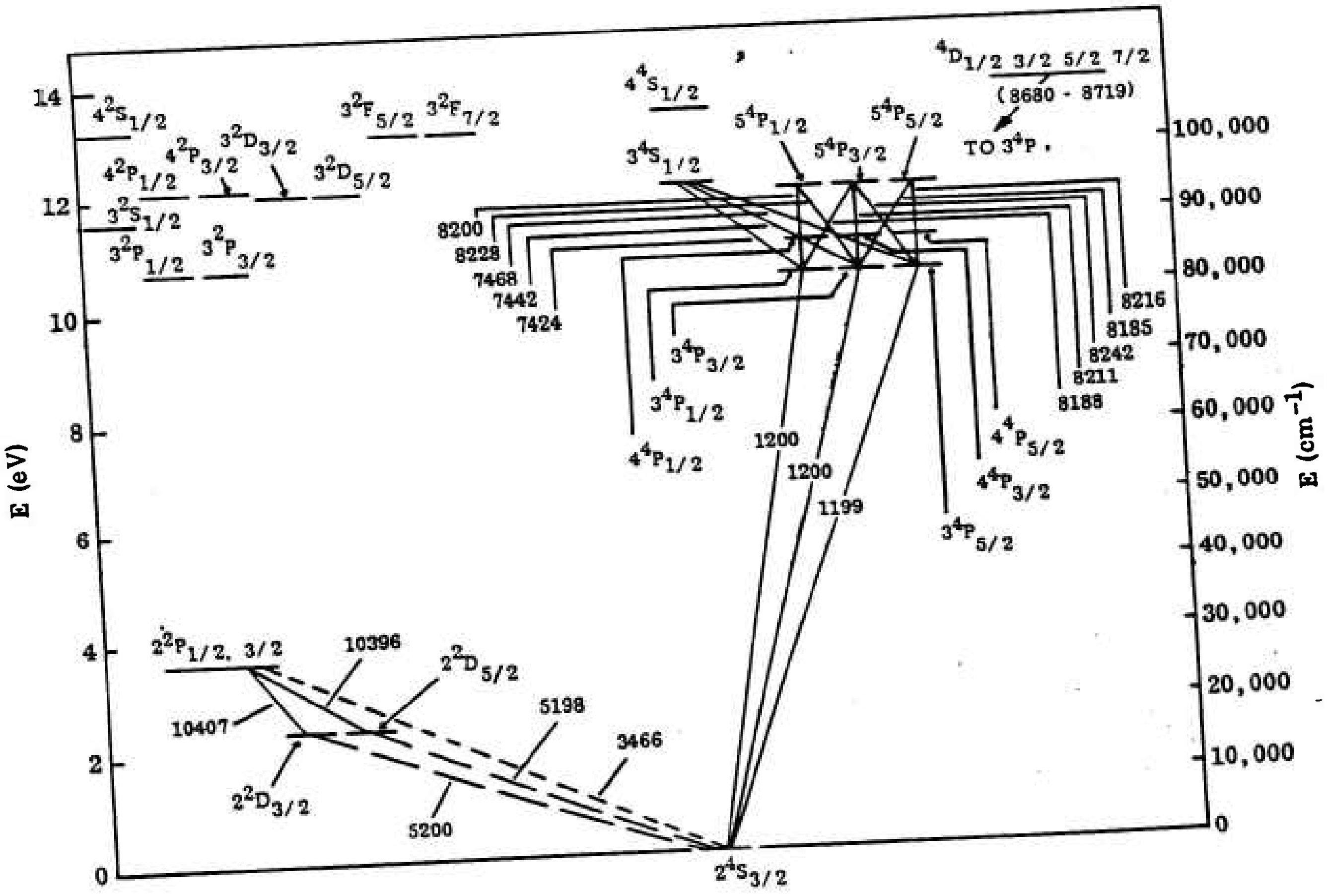

Figure B.2-2. Partial Grotrian diagram of atomic nitrogen. (Source: R-10, Figure 2)

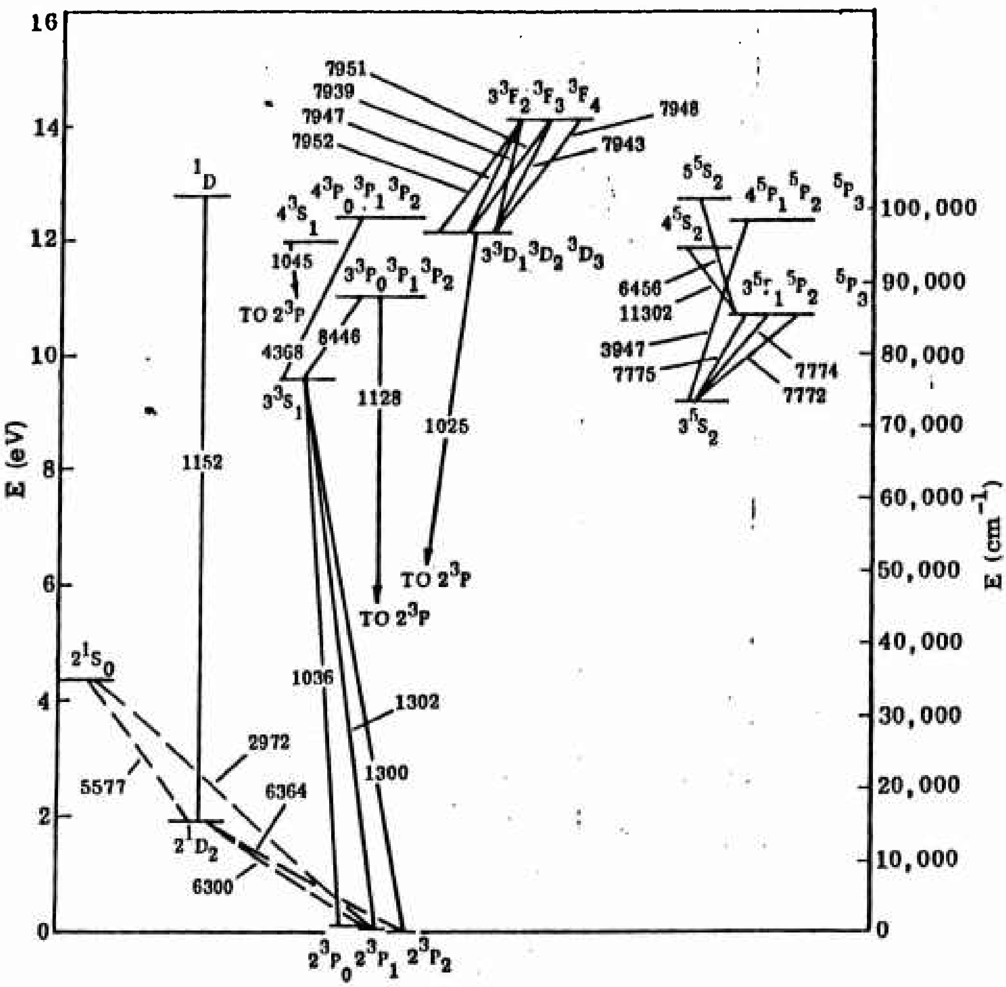

Figure B.2-3. Partial Grotrian diagram of atomic oxygen. (Source: R-10, Figure 3)

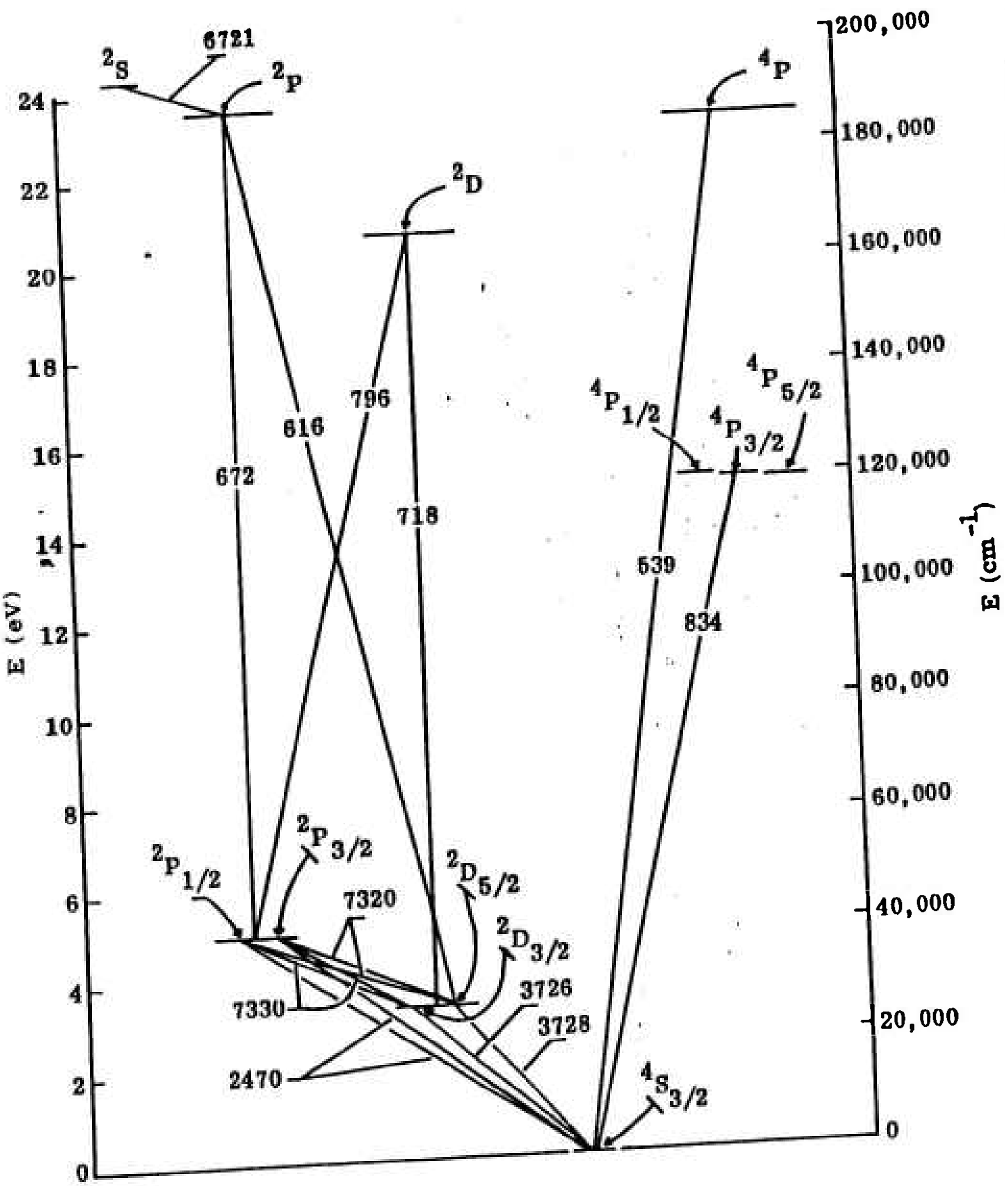

Figure B. 2-4. Partial Grotrian diagram of O^+.
(Source: R-10, Figure 4)

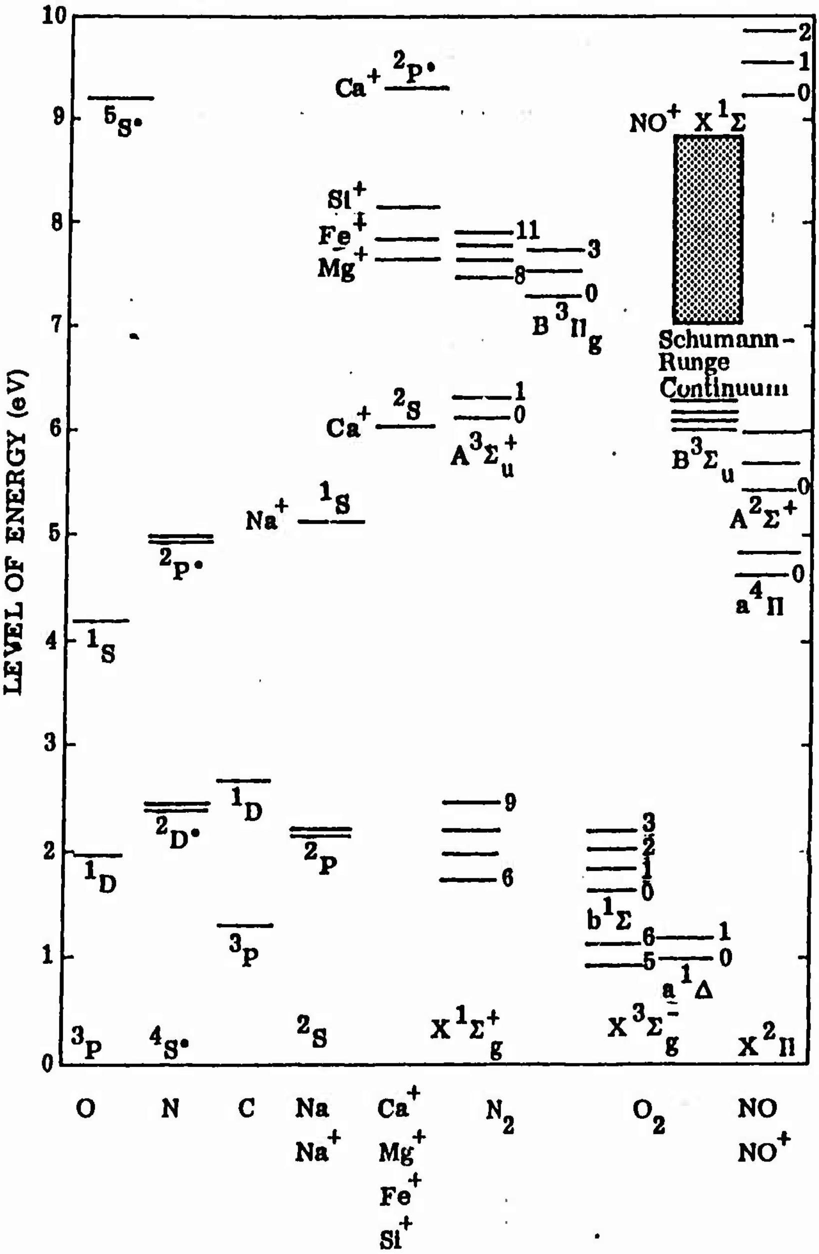

Figure B.2-5. Energy levels of pertinent atoms, molecules, and metallic ions. (Source: R-20, Figure 1)

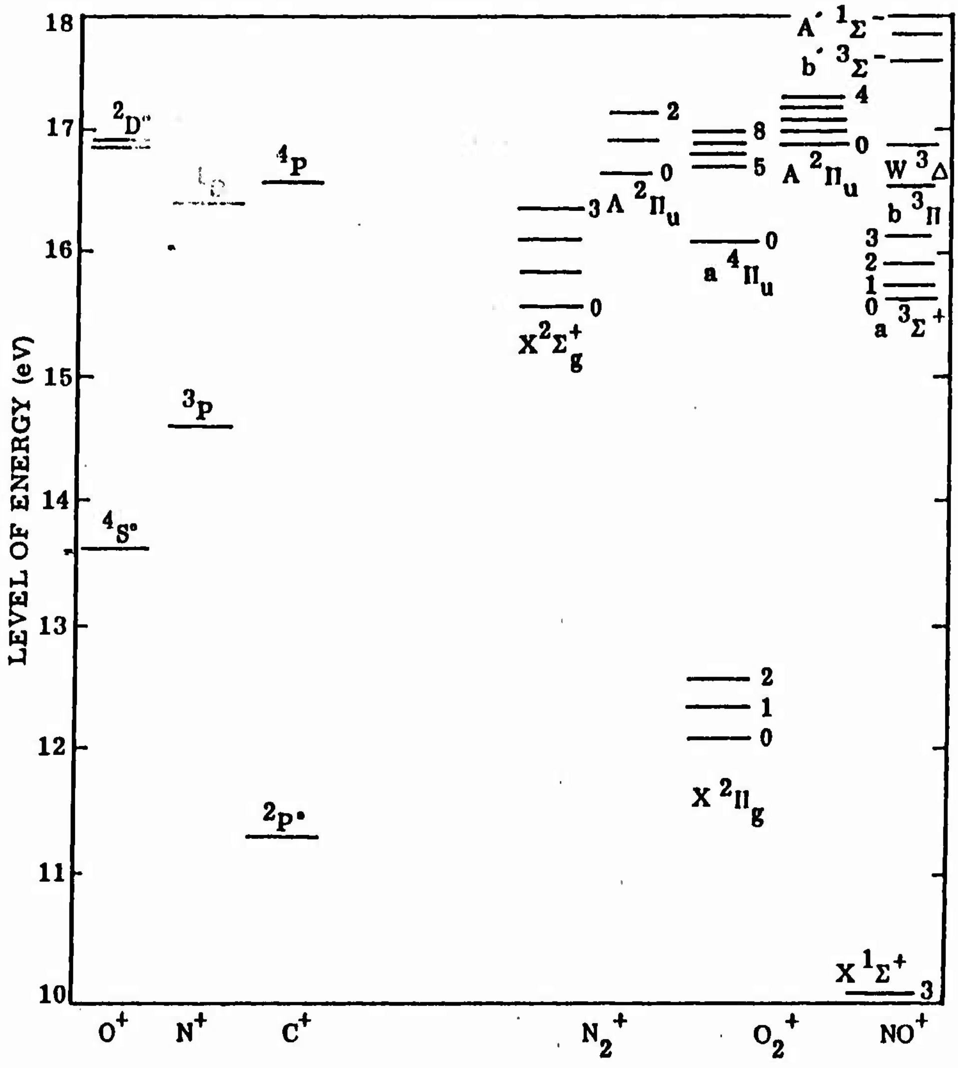

Figure B.2-6. Energy levels of pertinent ions above those of corresponding ground-state neutral species. (Source: R-20, Figure 2)

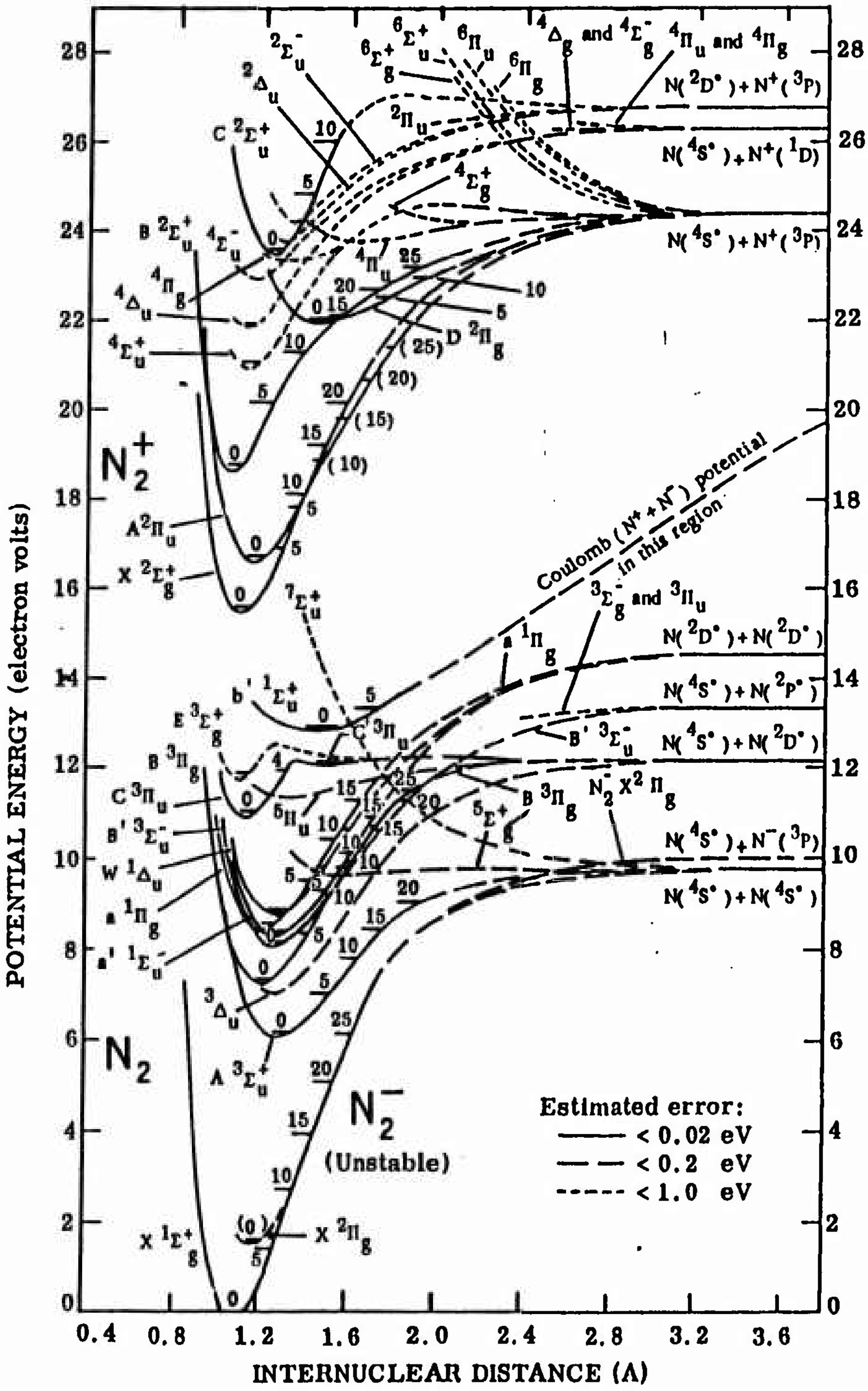

Figure B.2-7. Potential-energy curves for N_2^- (unstable), N_2, and N_2^+. (Source: R-10, Figure 5)

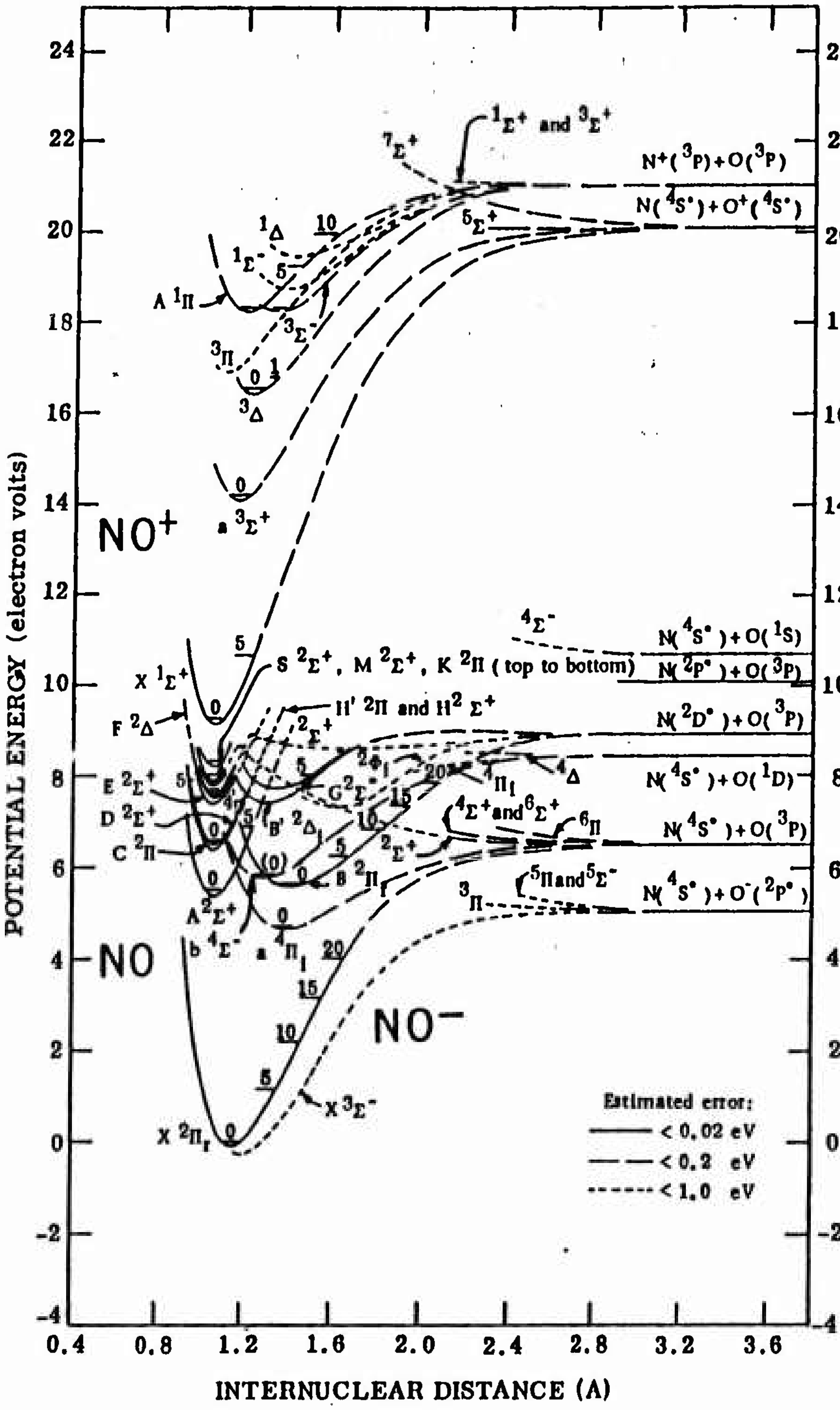

Figure B.2-8. Potential-energy curves for NO^-, NO, and NO^+. (Source: R-10, Figure 6)

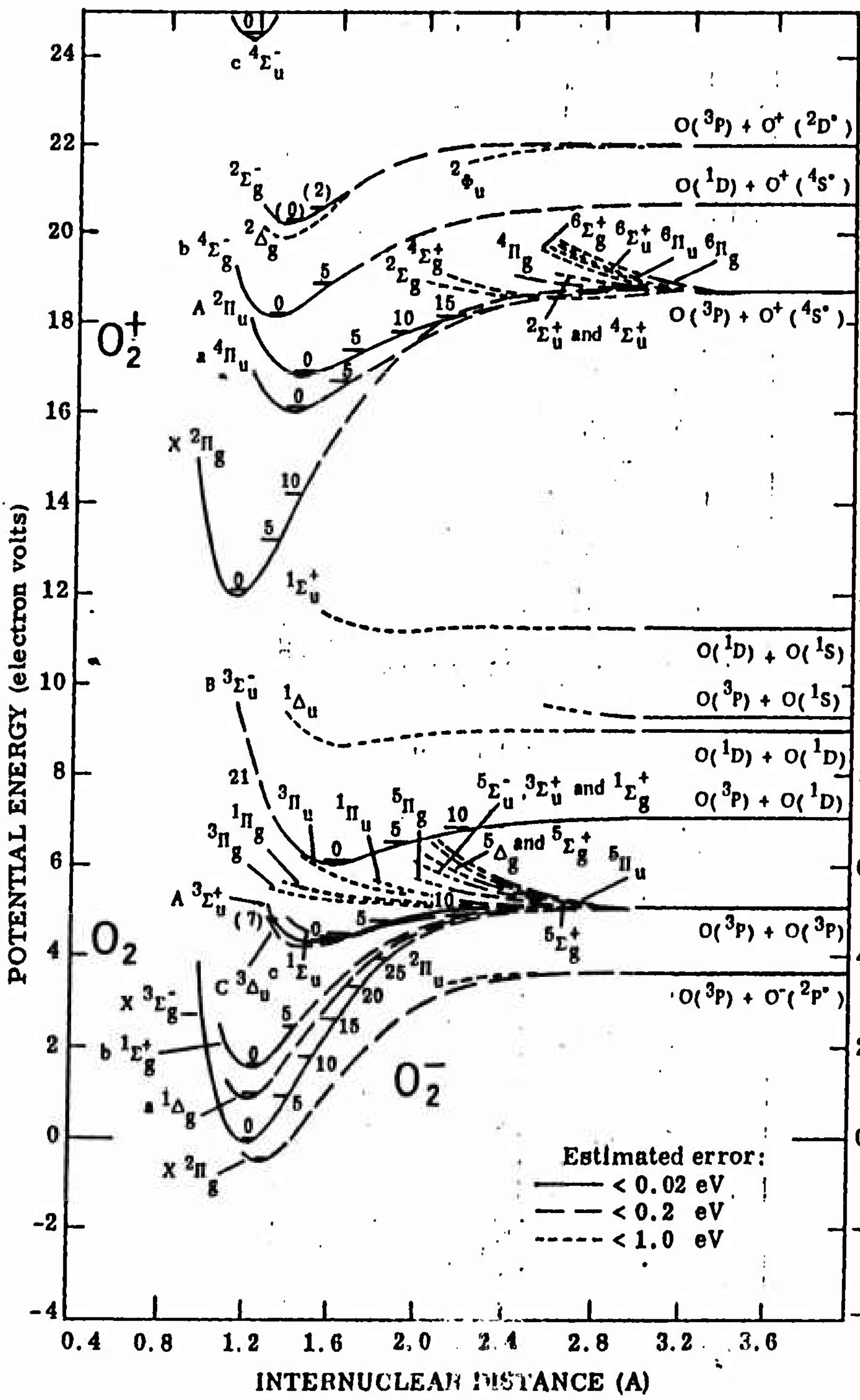

Figure B.2-9. Potential energy curves for O_2^-, O_2, and O_2. (Source: R-10, Figure 7)

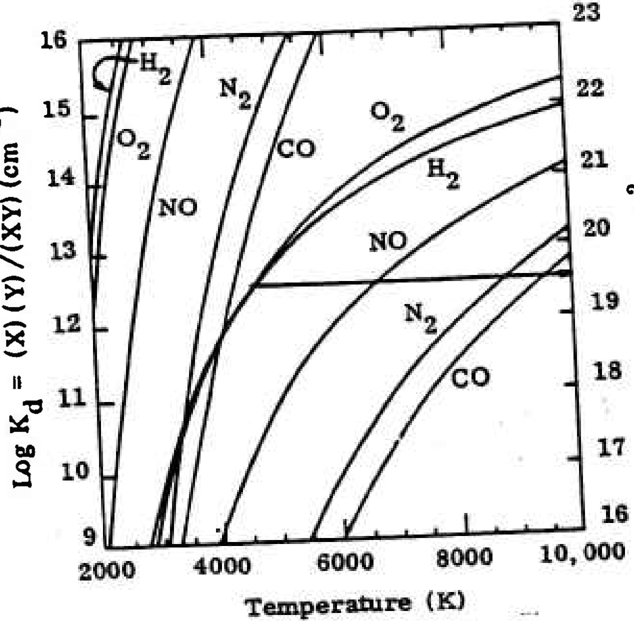

Figure B.2-10. Equilibrium constants for dissociation. (Source: R-10, Figure 8)

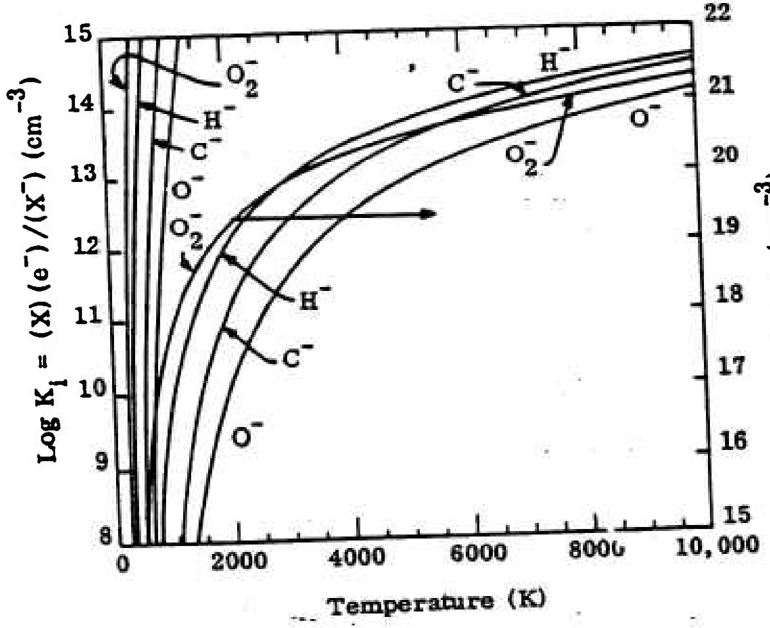

Figure B.2-11. Equilibrium constants for ionization (detachment) of negative ions. (Source: R-10, Figure 9)

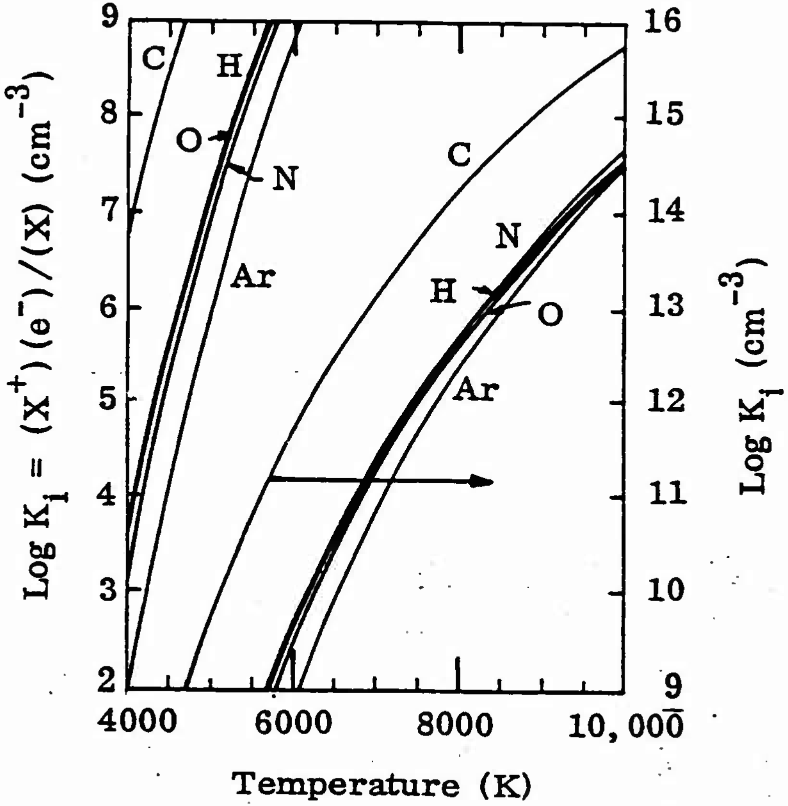

Figure B.2-12. Equilibrium constants for ionization of atoms. (Source: R-10, Figure 10)

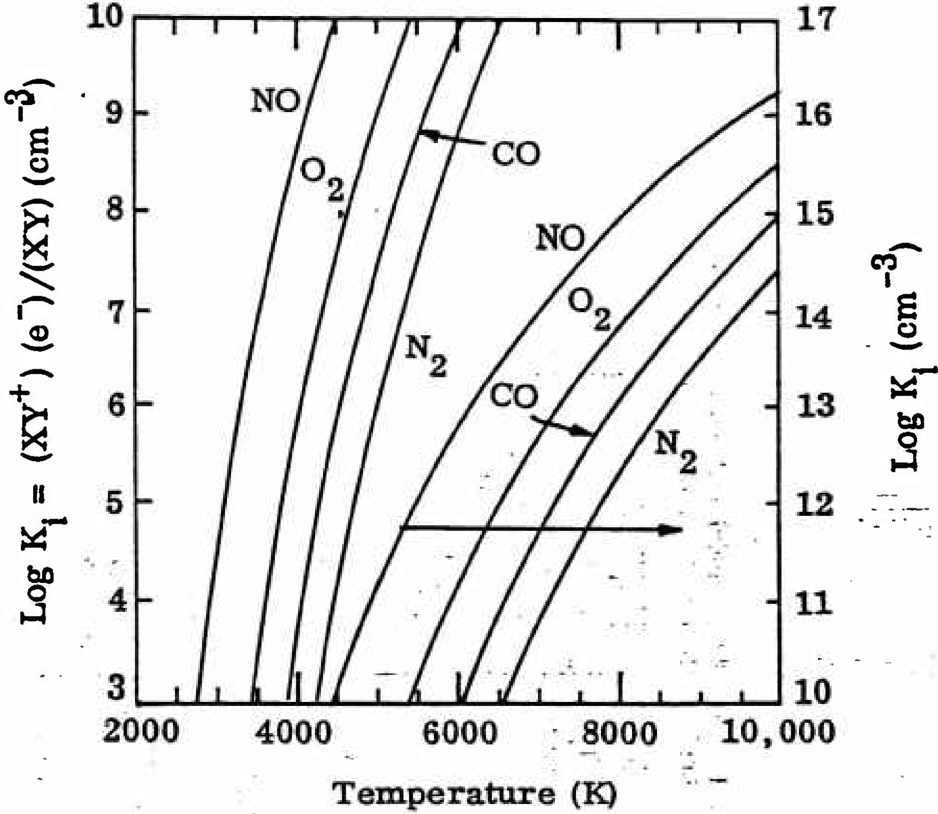

Figure B.2-13. Equilibrium constants for ionization of diatomic molecules. (Source: R-10, Figure 11)

Table B.2-1. Molecular weights and energies of formation, dissociation, and ionization for selected atoms and molecules. (Source: R-10, Table 1)

Species	Molec. Weight	Energy (or Heat) of Formation	Dissociation Energy	Ionization Energy
H^-	1.00852	1.485 eV 11.974×10^3 cm^{-1} 34.235 kcal/mole	--	0.754 6.083 17.392
H	1.00797	2.239 18.057 51.627	--	13.598 109.679 313.585
H^+	1.00742	15.837 127.736 365.213	--	--
C^-	12.01170	6.24 50.4 144.0	--	1.13 9.1 26.0
C	12.01115	7.371 59.452 169.979	--	11.259 90.814 259.648
C^+	12.001060	18.630 150.265 429.627	--	24.382 196.659 562.272
N	14.0067	4.880 39.359 112.532	--	14.534 117.225 335.160
N^+	14.0062	19.414 156.584 447.692	--	29.601 238.751 682.618
O^-	15.9999	1.079 8.705 24.89	--	1.478 11.925 34.10
O	15.9994	2.558 20.630 58.984	--	13.618 109.837 314.037
O^+	15.9989	16.175 130.467 373.021	--	35.117 283.244 809.829
Ar	39.948	0 0 0	--	15.759 127.110 363.423
Ar^+	39.947	15.759 127.110 363.423	--	27.629 222.848 637.149

Table B.2-1. (Continued)

Species	Molec. Weight	Energy (or Heat) of Formation	Dissociation Energy	Ionization Energy
H_2	2.01594	0 eV 0 $\times 10^3$ cm^{-1} 0 kcal/mole	4.478 36.118 103.266	15.426 124.418 355.727
H_2^+	2.01539	15.426 124.418 355.727	2.651 21.379 61.125	--
CO	28.0106	-1.179 -9.513 -27.200	11.108 89.595 256.163	14.013 113.029 323.163
CO^+	28.0100	12.834 103.516 295.963	8.354(C^+-O) 67.380 192.648	27.8 224.0 640.0
N_2	28.0134	0 0 0	9.759 78.717 225.061	15.580 125.667 359.297
N_2^+	28.0129	15.580 125.667 359.297	8.711 70.264 200.893	27.1 219.0 626.0
NO^-	30.0066	0.911 7.35 21.00	5.049(N-O^-) 40.72 116.42	0.020 0.16 0.46
NO	30.0061	0.931 7.506 21.46	6.507 52.483 150.055	9.267 74.747 213.711
NO^+	30.0056	10.198 82.253 235.17	10.857(N-O^+) 87.573 250.382	30.5 246.0 703.0
O_2^-	31.9993	-0.429 -3.46 -9.89	4.066 32.80 93.76	0.429 3.46 9.89
O_2	31.9988	0 0 0	5.115 41.260 117.967	12.063 97.295 278.178
O_2^+	31.9983	12.063 97.295 278.178	6.670 53.802 153.826	24.2 195.0 558.0
OH^-	17.0079	-1.43 -11.51 -32.9	4.75(O^--H) 38.27 109.4	1.83 14.75 42.2
OH	17.0074	0.401 3.24 9.26	4.395(O-H) 35.45 101.33	12.94 104.4 298.4

Table B.2-1. (Continued)

Species	Molec. Weight	Energy (or Heat) of Formation	Dissociation Energy	Ionization Energy
OH^+	17.0068	13.34 eV 107.6×10^3 cm^{-1} 307.7 kcal/mole	5.05(O-H^+) 40.7 116.5	--
H_2O	18.0153	-2.476 -19.972 -57.103	5.116(H-OH) 41.27 117.98	12.619 101.78 291.0
H_2O^+	18.0148	10.143 81.81 233.9	5.84(H-OH^+) 47.1 134.7	--
CO_2	44.0100	-4.075 -32.865 -93.965	5.453(CO-O) 43.982 125.750	13.769 111.06 317.5
CO_2^+	44.0094	9.694 78.19 223.5	5.179(CO-O^+) 41.77 119.4	22.6 182.0 521.0
NO_2^-	46.0060	-2.1 -17.0 -49.0	4.1(NO-O^-) 33.0 94.0	2.5 20.0 58.0
NO_2	46.0055	0.372 3.00 8.59	3.116(NO-O) 25.13 71.86	9.78 78.9 225.6
NO_2^+	46.0050	10.15 81.9 234.2	2.60(NO^+-O) 21.0 60.0	--
N_2O	44.0128	0.881 7.107 20.32	1.677(N_2-O) 13.523 38.66	12.894 104.00 297.35
N_2O^+	44.0123	13.775 111.11 317.67	1.302(N-NO^+) 10.50 30.02	--
O_3^-	47.9987	-0.6 -5.0 -13.0	1.7(O_2-O^-) 14.0 38.0	2.1 17.0 48.0
O_3	47.9982	1.506 12.15 34.74	1.051(O_2-O) 8.48 24.25	12.80 103.2 295.2
O_3^+	47.9977	14.31 115.4 329.9	0.32(O_2^+-O) 2.5 7.3	--

Table B.2-2. Energy levels of CO.
(Source: R-10, Table 12)

		STATE						
		$X^1\Sigma^+$	$a^3\Pi$	$a'^3\Sigma^+$	$d^3\Delta$	$e^3\Sigma^-$	$I^1\Sigma^-$	$A^1\Pi$
ENERGY	(CM-1)	0	48474	55354	60647	63709	64547	64747
	(EV)	0.0000	6.0099	6.8628	7.5191	7.8987	8.0026	8.0273
VIB. INT.	(CM-1)	2143	1715	1209	1138	1094	1071	1481
	(EV)	0.2657	0.2126	0.1499	0.1410	0.1357	0.1328	0.1836

Table B.2-3. Energy levels of N_2.
(Source: R-10, Table 13)

		STATE							
		$X^1\Sigma_g^+$	$A^3\Sigma_u^+$	$B^3\Pi_g$	$W^3\Delta_u$	$B'^3\Sigma_u^-$	$a'^1\Sigma_u^-$	$a^1\Pi_g$	$w^1\Delta_u$
ENERGY	(CM-1)	0	49756	59310	59329	65852	67739	68951	71698
	(EV)	0.0000	6.1688	7.3533	7.3557	8.1644	8.3984	8.5486	8.8892
VIB. INT.	(CM-1)	2330	1433	1705	1505	1493	1506	1666	1536
	(EV)	0.2888	0.1777	0.2114	0.1866	0.1851	0.1867	0.2066	0.1904

Table B.2-4. Energy levels of N_2^+.
(Source: R-10, Table 14)

		STATE							
		$X^2\Sigma_g^+$	$A^2\Pi_u$	$B^2\Sigma_u^+$	$^4\Sigma_u^+$	$^4\Delta_u$	$D^2\Pi_g$	$^4\Sigma_u^-$	$C^2\Sigma_u^+$
ENERGY	(CM-1)	0	8068	25566	44328	51328	51203	60328	64542
	(EV)	0.0000	1.0003	3.1697	5.4958	6.3637	6.3482	7.4795	8.0020
VIB. INT.	(CM-1)	2175	1873	2371	1668	1572	889	1472	2051
	(EV)	0.2696	0.2323	0.2940	0.2068	0.1949	0.1102	0.1825	0.2543

Table B.2-5. Energy levels of NO.
(Source: R-10, Table 15)

		STATE							
		$X^2\Pi$	$a^4\Pi$	$A^2\Sigma^+$	$B^2\Pi$	$b^4\Sigma^-$	$C^2\Pi$	$D^2\Sigma^+$
ENERGY	(CM-1)	62	~37965	44199	45505	~47092	52380	53291
	(EV)	0.0077	~4.7069	5.4799	5.6418	~5.8385	6.4941	6.6071
VIB. INT.	(CM-1)	1876	995	2342	1023	~1203	2365	2279
	(EV)	0.2326	0.1234	0.2903	0.1268	~0.14[illegible]1	0.2932	0.2826

Table B.2-6. Energy levels of NO^+
(Source: R-10, Table 16)

		STATE							
		$X^1\Sigma^+$	$a^3\Sigma^+$	$b^3\Pi$	$w^3\Delta$	$b'^3\Sigma^-$	$A'^1\Sigma^-$	$W^1\Delta$	$A^1\Pi$
ENERGY	(CM-1)	0	51470	58810	61250	67090	68910	70850	73084
	(EV)	0.0000	6.3813	7.2913	7.5938	8.3179	8.5435	8.7841	9.0610
VIB.	(CM-1)	2344	1258	1698	1306	1290	1253	1216	1561
INT.	(EV)	0.2907	0.1560	0.2105	0.1619	0.1599	0.1553	0.1508	0.1935

Table B.2-7. Energy levels of O_2.
(Source: R-10, Table 17)

		STATE						
		$X^3\Sigma_g^-$	$a^1\Delta_g$	$b^1\Sigma_g^+$	$c^1\Sigma_u^-$	$C^3\Delta_u$	$A^3\Sigma_u^+$	$B^3\Sigma_u^-$
ENERGY	(CM-1)	0	7882	13121	32664	34329	35009	49358
	(EV)	0.0000	0.9773	1.6267	4.0497	4.2561	4.3404	6.1194
VIB.	(CM-1)	1556	1483	1405	768	820	771	688
INT.	(EV)	0.1930	0.1839	0.1742	0.0952	0.1017	0.0956	0.0853

Table B.2-8. Energy levels of O_2^+.
(Source: R-10, Table 18)

		STATE			
		$X^2\Pi_g$	$a^4\Pi_u$	$A^2\Pi_u$	$b^4\Sigma_g^-$
ENERGY	(CM-1)	100	32624	40170	49291
	(EV)	0.0124	4.0448	4.9803	6.1111
VIB.	(CM-1)	1873	1015	871	1163
INT.	(EV)	0.2322	0.1258	0.1080	0.1441

Table B.2-9. Lower electronic and vibrational energy levels of selected diatomic molecules. (Source: R-10, Table 19)

Molecule	State	Electronic Energy	Lowest Vibrational Interval
H_2	$X^1\Sigma_g^+$	0 cm^{-1} 0 eV	4161 cm^{-1} 0.516 eV
H_2^+	$X^2\Sigma_g^+$	0 0	2191 0.272
CO^+	$X^2\Sigma^+$	0 0	2184 0.271
	$A^2\Pi$	20408 2.530	1535 0.190
	$B^2\Sigma^+$	45633 5.658	1679 0.208
NO^-	$X^3\Sigma^-$	0 0	(1355) (0.168)
O_2^-	$X^2\Pi_g$	0 0	(1065) (0.132)
OH^-	$X^1\Sigma^+$	0 0	(3600) (0.446)
OH	$X^2\Pi$	0 0	3570 0.443
	$A^2\Sigma^+$	32402 4.017	2989 0.371
OH^+	$X^3\Sigma^-$	0 0	2967 0.368
	$A^3\Pi$	27952 3.466	1986 0.246

Table B.2-10. Vibrational spacing of triatomic molecules. (Source: R-10, Table 20)

Molecule	Ground State	Vibrational Intervals		
		v_1	v_2	v_3
H_2O	$^1A_1$	3657 cm^{-1} 0.453 eV	1595 cm^{-1} 0.198 eV	3756 cm^{-1} 0.466 eV
H_2O^+	$(^2B_1)$	(~3200) (~0.40)	(~1500) (~0.19)	(~3300) (~0.41)
CO_2	$1\Sigma_g^+$	1388 0.172	667 0.083	2349 0.291
CO_2^+	$^2\Pi_g$	1280 0.159	(~400) (~0.05)	(1469) (0.182)
NO_2^-	$^1A_1$	(1280) (0.159)	(790) (0.098)	(1210) (0.150)
NO_2	$^2A_1$	(1320) (0.164)	750 0.093	1618 0.201
NO_2^+	$(1\Sigma_g^+)$	(1396) (0.173)	(571) (0.071)	(2360) (0.293)
N_2O	$1\Sigma+$	2224 0.276	589 0.073	1285 0.159
N_2O^+	$^2\Pi$	1737 0.215	461 0.057	1126 0.140
O_3^-	$(^2B_1)$	(1260) (0.156)	(800) (0.099)	(1140) (0.141)
O_3	$^1A_1$	1110 0.138	705 0.087	1042 0.129
O_3^+	$(^2A_1)$	(~1300) (~0.16)	(~700) (~0.09)	(~1600) (~0.20)

Table B.2-11. Stability of negative ions of possible ionospheric interest. (Source: R-17, Table 7)

Ion	Adiabatic Electron Affinity (eV)	Dissociation Energy (eV)		Vertical Detachment Energy (eV)
NO^-	0.024	$(O^- \cdot N)$	5.2	< 1.0
O_2^-	0.43 ± 0.01	$(O^- \cdot O)$	4.08	≤ 0.5
O_4^-	1.0	$(O_2^- \cdot O_2)$	0.54	≥ 1.0
$O_2^-(H_2O)$	1.2	$(O_2^- \cdot H_2O)$	0.8	≥ 1.2
CO_4^-	1.2 ± 0.1	$(O_2^- \cdot CO_2)$	0.8 ± 0.08	≥ 1.2
$H_3O_2^-$	≤ 1.2	$(OH^- \cdot H_2O)$	≤ 1.2	2.95
SF_6^-	~ 1.4	$(SF_5^- \cdot F)$	≤ 1.4	
O^-	1.47 ± 0.01			1.47 ± 0.1
$O_2^-(H_2O)_2$	1.95	$(O_2^-(H_2O) \cdot H_2O)$	0.75	≥ 1.95
O_3^-	1.9	$(O^- \cdot O_2)$	1.4	2.1
		$(O_2^- \cdot O)$	2.5	
$O_2^-(H_2O)_3$	2.6	$(O_2^-(H_2O)_2 \cdot H_2O)$	0.67	> 2.6
NO_2^-	2.5 ± 0.2	$(O^- \cdot NO)$	4.1	2.75
$O_2^-(H_2O)_4$	3.2	$(O_2^-(H_2O)_3 \cdot H_2O)$	0.6	> 3.2
$O_2^-(H_2O)_5$	3.7	$(O_2^-(H_2O)_4 \cdot H_2C)$	0.5	> 3.7
NO_3^-	Unknown	$(O_2^- \cdot NO)$	> 2.5	
	3.6 ± 0.2	$(O^- \cdot NO_2)$	4.3	

Table B.2-12. Radiative lifetimes and transitions for principal atmospheric species. (Source: R-20, Table 1)

Species and State	Mean Radiative Lifetime (sec)	Principal Transition; λ (in A); Name of Transition	Approx. ΔE_{if} (eV)
ATOMS AND ATOMIC IONS			
$C(^3P)$	Ground State		
(^1D)	3.2×10^3	$^3P \leftarrow {}^1D$; 9823, 9850	1.26
(^1S)	2.0	$^1D \leftarrow {}^1S$; 8727	1.42
$(2p^3\ ^5S^o)$	0.03	$^3P \leftarrow {}^5S$; 2965, 2967	4.18
$C^+(^2P^o)$	Ground State		
(^4P)	Mod. long	$^2P^o \leftarrow {}^4P$; ~2330	5.35
$N(^4S^o)$	Ground State		
$(^2D^o{}_{3/2})$	6.1×10^4	$^4S^o \leftarrow {}^2D^o{}_{3/2}$; 5200 (nebular)	2.38
$(^2D^o{}_{1/2})$	1.4×10^5	$^4S^o \leftarrow {}^2D^o{}_{5/2}$; 5201	2.38
$(^2P^o)$	13	$^2D^o \leftarrow {}^2P^o$; 10,396; 10,404	1.19
$(3s\ ^4P)$	2.5×10^{-9}	$^4S^o \leftarrow {}^4P$; 1200, 1201	10.31
$N^+(^3P)$	Ground State		
(^1D)	250	$^3P \leftarrow {}^1D$; 6584, 6548	1.89
(^1S)	0.90	$^1D \leftarrow {}^1S$; 5755	2.15
$O(^3P)$	Ground State		
(^1D)	148	$^3P \leftarrow {}^1D$; 6300, 6364 (red lines)	1.96
(^1S)	0.80	$^1D \leftarrow {}^1S$; 5577 (green line)	2.22
$(3s\ ^5S^o)$	0.0006	$^3P \leftarrow {}^5S^o$; 1356, 1359	9.13
$(3s\ ^3S^o)$	1.8×10^{-9}	$^3P \leftarrow 3S^o$; 1302, 1305, 1306	9.51
$O^+(^4S^o)$	Ground State		

Table B.2-12. (Continued)

Species and State	Mean Radiative Lifetime (sec)	Principal Transition; λ(in A); Name of Transition	Approx. ΔE_{if} (eV)
ATOMS AND ATOMIC IONS (Cont'd.)			
$O^+(^2D^o_{3/2})$	5.9×10^3	$^4S^o \leftarrow {^2D^o}_{3/2}$; 3726 (nebular)	3.33
$(^2D^o_{5/2})$	2.1×10^4	$^4S^o \leftarrow {^2D^o}_{5/2}$; 3729	3.32
$(^2P^o_{1/2})$	5.4	$^2D^o \leftarrow {^2P^o}_{1/2}$; 7319, 7330 (auroral)	1.69
$(^2P^o_{3/2})$	4.2	$^2D^o \leftarrow {^2P^o}_{3/2}$; 7319, 7330	1.69
DIATOMIC MOLECULES AND MOLECULAR IONS			
$N_2(X\,^1\Sigma_g^+)$	Ground State		
$(A\,^3\Sigma_u^+)$	1.3 (F_2); 2.7 (F_1, F_3)	A → X (Vegard-Kaplan)	6.2
$(B\,^3\Pi_g)$	8.0×10^{-6}	B → A; 10,510 (first positive)	1.2
$(W\,^3\Delta_u)$	Long	W → X W → B	7.4 0.003
$(B'\,^3\Sigma_u^-)$	10^{-5} est.	B' → B (Y bands)	0.8
$(a'\,^1\Sigma_u^-)$	≥0.04	a' → X (Wilkinson)	8.4
$(a\,^1\Pi_g)$	1.4×10^{-4}	a → X; 1450 (Lyman-Birge-Hopfield)	8.6
$(w\,^1\Delta_u)$	10^{-4} est.	w → a; 36,400	0.3
$N_2^+(X\,^2\Sigma_g^+)$	Ground State		
$(A\,^2\Pi_u)$	1.2×10^{-5} (v = 3)	A → X; 11,036 (Meinel)	1.0
$(B\,^2\Sigma_u^+)$	5.9×10^{-8}	B → X; 3914 (first negative)	3.2
$(^4\Sigma_u^+)$	Mod. Long	$^4\Sigma_u^+ \rightarrow X$	~6
$NO(X\,^2\Pi)$	Ground State		
$(a\,^4\Pi)$	~0.16	a → X	4.7

Table B.2-12. (Continued)

Species and State	Mean Radiative Lifetime (sec)	Principal Transition; λ (in A); Name of Transition	Approx. ΔE_{if} (eV)
DIATOMIC MOLECULES AND MOLECULAR IONS (Cont'd.)			
$NO(A\ ^2\Sigma^+)$	2.0×10^{-7}	$A \rightarrow X$; 2265 (γ bands)	5.5
$(B\ ^2\Pi)$	3.6×10^{-6}	$B \rightarrow X$; (β bands)	5.6
$NO^+(X\ ^1\Sigma^+)$	Ground State		
$(a\ ^3\Sigma^+)$	Long	$a \rightarrow X$	6.4
$(b\ ^3\Pi)$	1.4×10^{-4}	$b \rightarrow a$	0.9
$(w\ ^3\Delta)$	$\sim 10^{-4}$ est.	$w \rightarrow b$	0.3
$NO_2(^2B_1)$	5.5×10^{-5} to 9.0×10^{-5}	$A\ ^2B_1 \rightarrow X\ ^2A_1$	
$O_2(X\ ^3\Sigma_g^-)$	Ground State		
$(a\ ^1\Delta_g)$	3.9×10^3	$a \rightarrow X$; 12,680 (infrared atmospheric)	0.98
$(b\ ^1\Sigma_g^+)$	12	$b \rightarrow X$; 7619 (atmospheric)	1.63
$(c\ ^1\Sigma_u^-)$	Long	$c \rightarrow X$; 2856 (Herzberg II)	4.0
$(C\ ^3\Delta_u)$	Long	$C \rightarrow X$ (Herzberg III) $C \rightarrow a$	~4.2
$(A\ ^3\Sigma_u^+)$	0.03	$A \rightarrow X$; 2856 (Herzberg I) $A \rightarrow b$; 4586 (Broida-Gaydon)	4.3
$(B\ ^3\Sigma_u^-)$	4.2×10^{-8}	$B \rightarrow X$; 2030 (Schumann-Runge)	6.1
$O_2^+(X\ ^2\Pi_g)$	Ground		
$(a\ ^4\Pi_u)$	Long	$a \rightarrow X$; 6026	4.0
$(A\ ^2\Pi_u)$	7×10^{-7}	$A \rightarrow X$ (second negative)	5.0
$(b\ ^4\Sigma_g^-)$	1.1×10^{-6}	$b \rightarrow a$; 6026 (first negative)	2.1

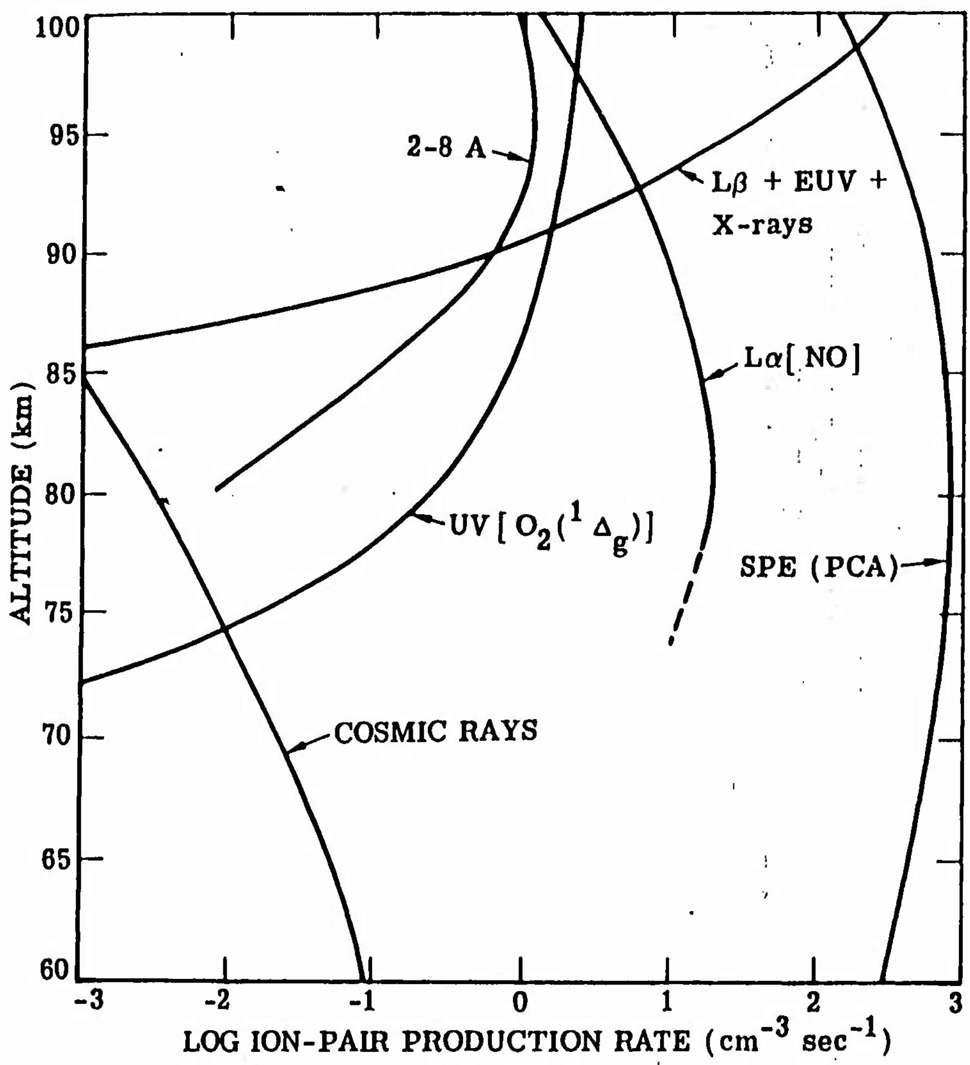

Figure B.3.a-1. Daytime D-region ionization rates. (Source: R-5, Figure 4)

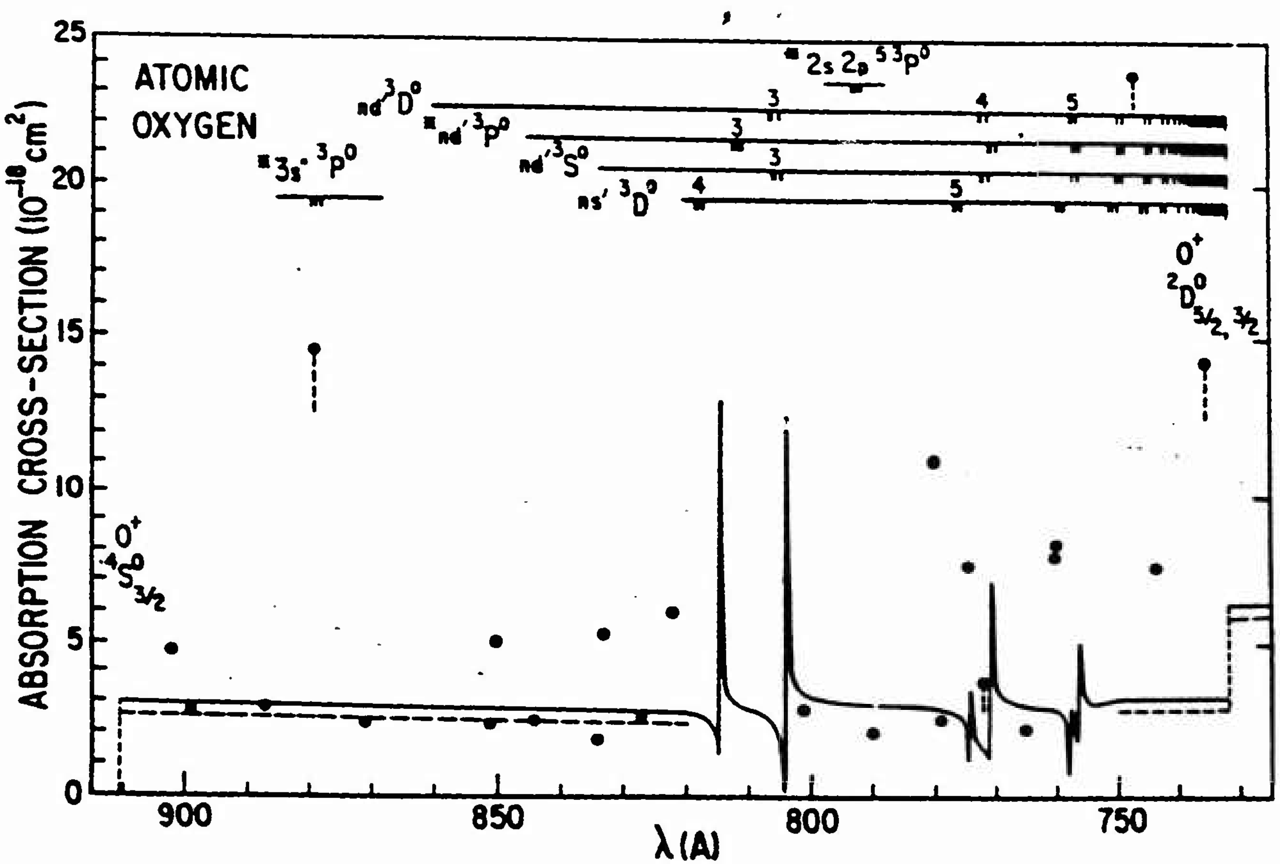

Figure B.3.a-2. Atomic oxygen cross-sections: Ionization threshold (^4S) to ^2D limit. (Source: R-12, Figure 8)

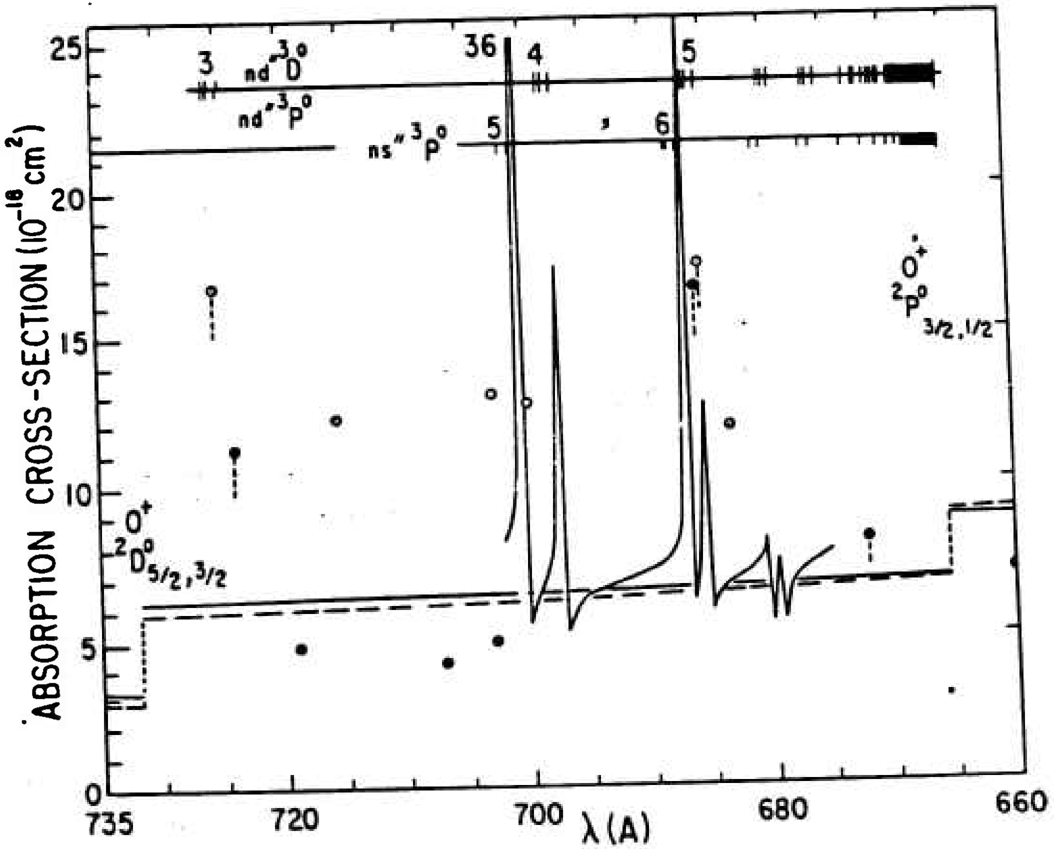

Figure B.3.a-3. Atomic oxygen cross-sections: ^2D threshold to ^2P limit. (Source: R-12, Figure 9)

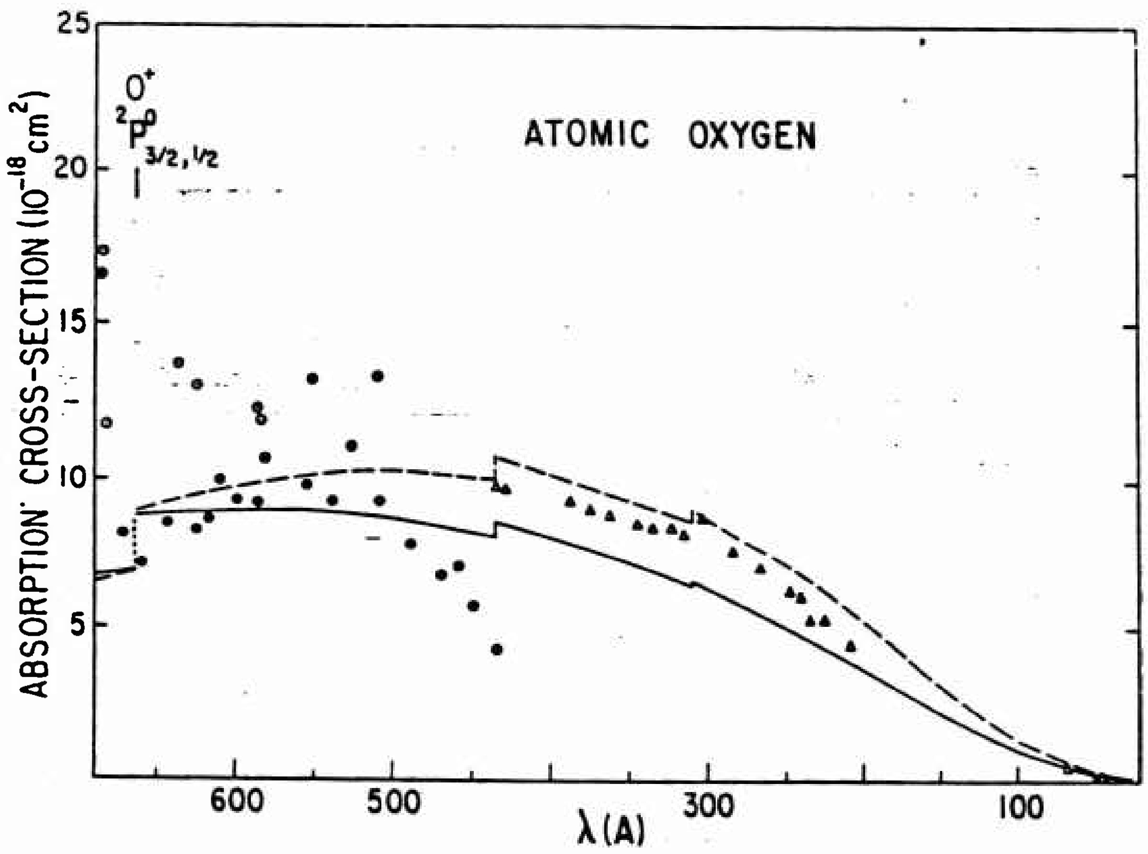

Figure B.3.a-4. Atomic oxygen cross-sections: ^2P threshold to shorter wavelengths. (Source: R-12, Figure 10)

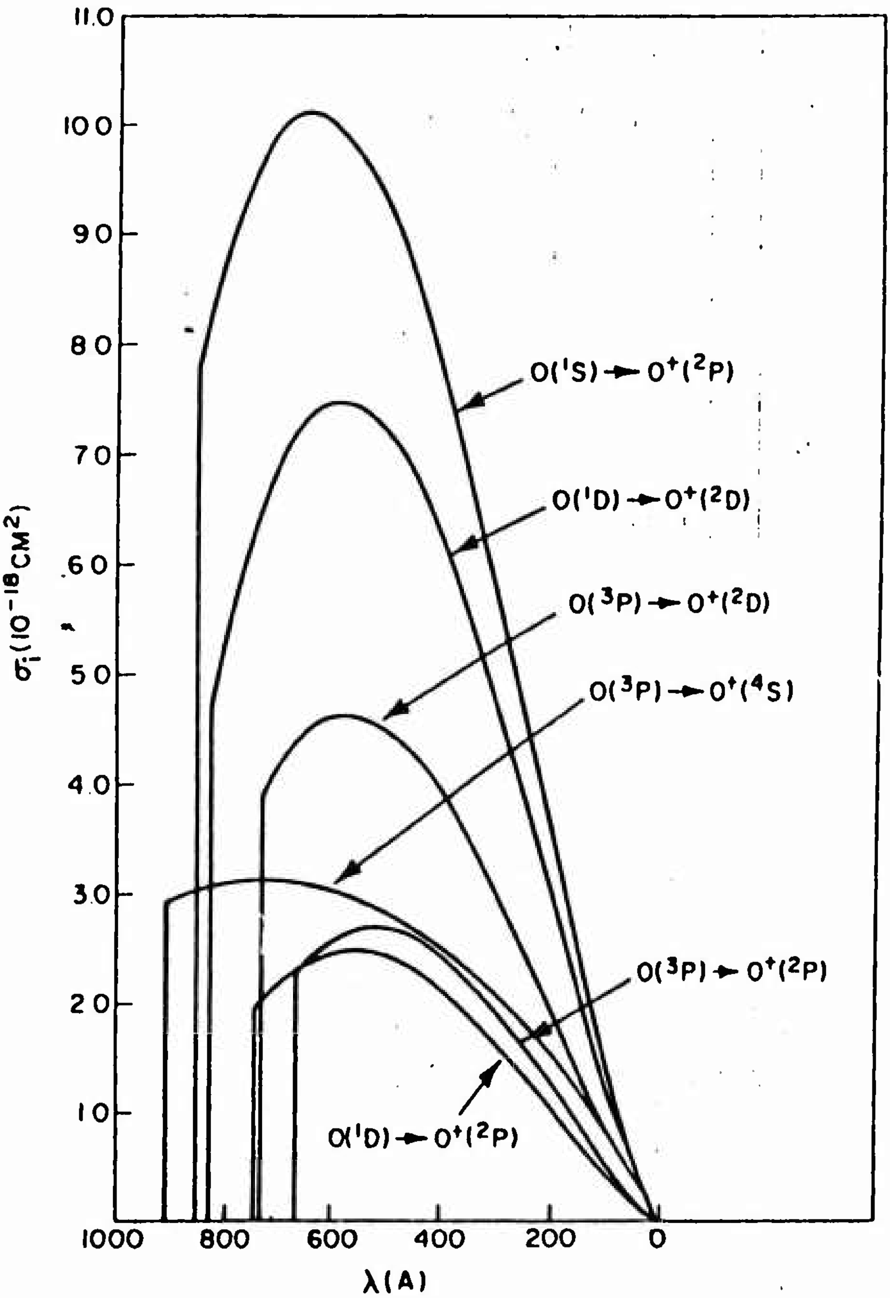

Figure B.3.a-5. Atomic oxygen photoionization cross-sections for specific initial and final states. (Source: R-12, Figure 11)

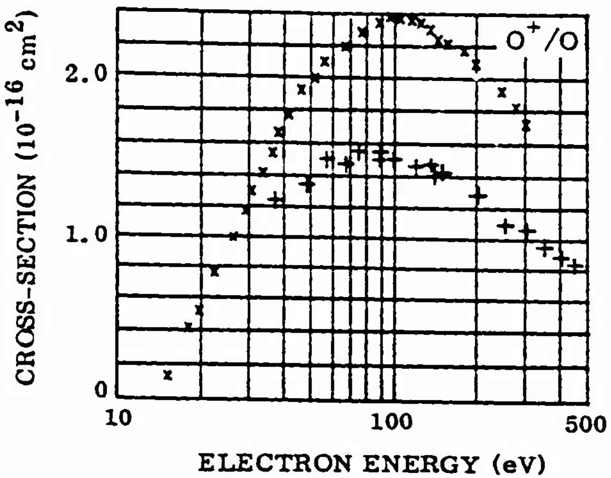

Figure B.3.a-6. (Source: R-14, Figure 8)

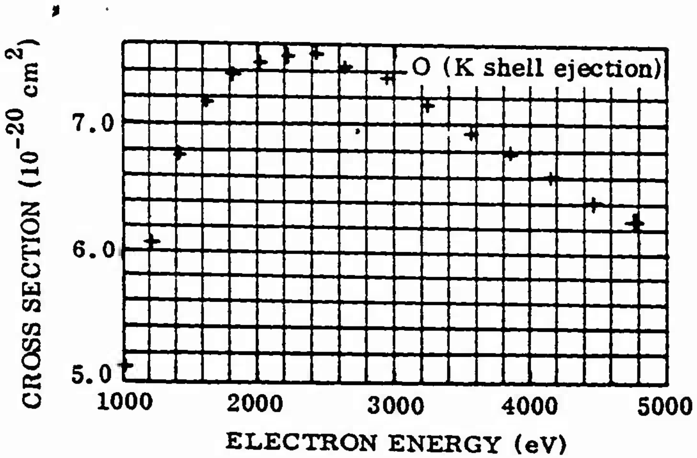

Figure B.3.a-7. (Source: R-14, Figure 9)

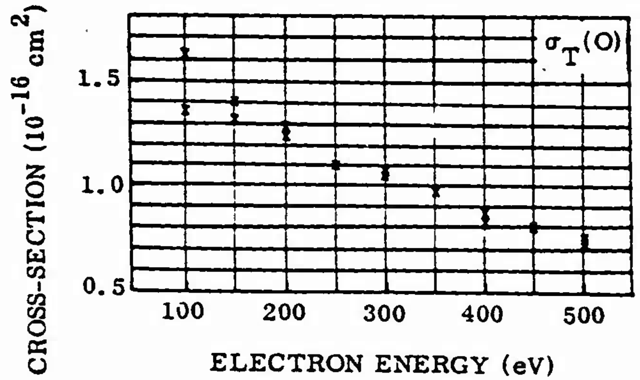

Figure B.3.a-8. (Source: R-14, Figure 7)

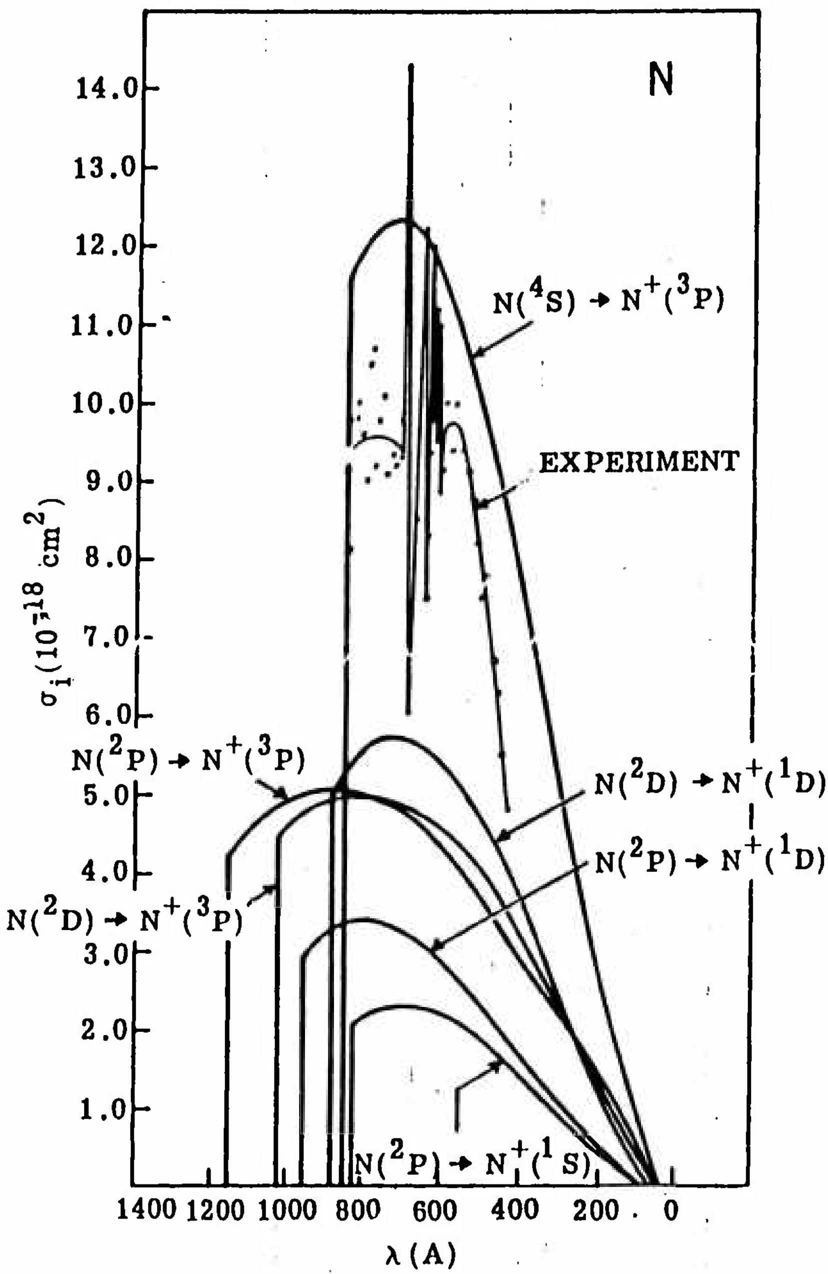

Figure B.3.a-9. Atomic nitrogen photoionization cross-sections for specific initial and final states. (Source: R-12, Figure 12)

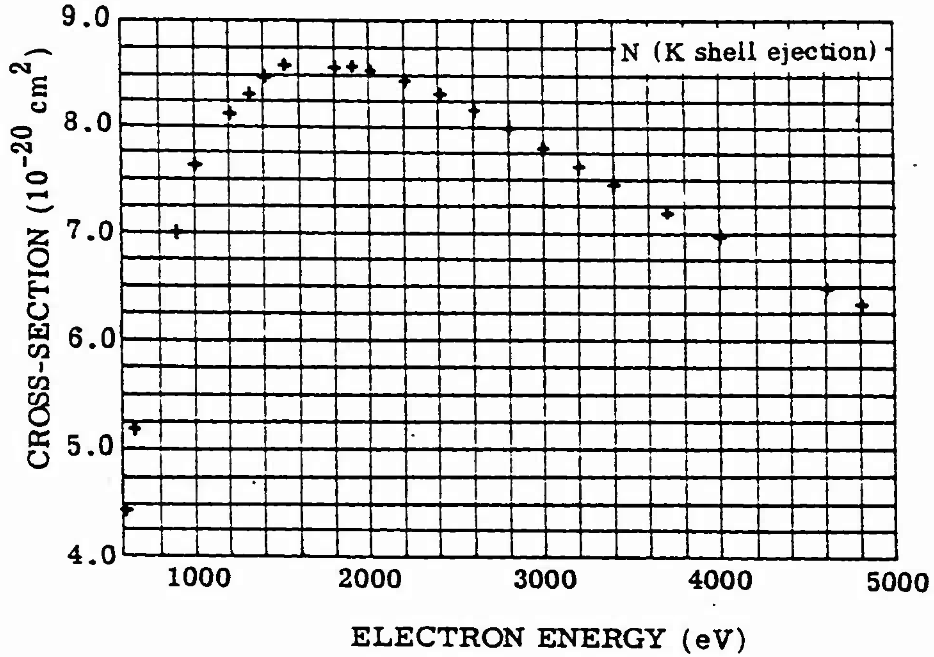

Figure B.3.a-10. (Source: R-14, Figure 6)

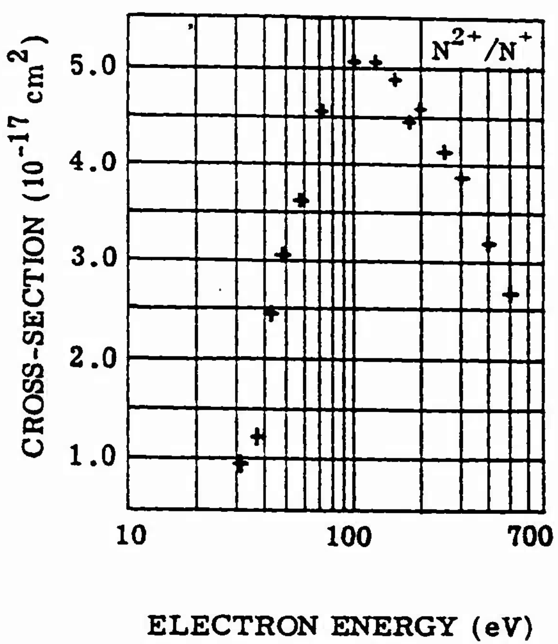

Figure B.3.a-11. (Source: R-14, Figure 11)

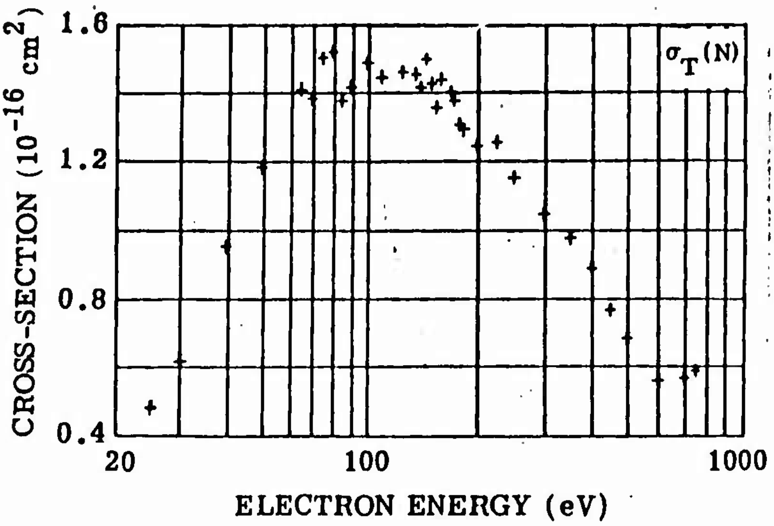

Figure B.3.a-12. (Source: R-14, Figure 5)

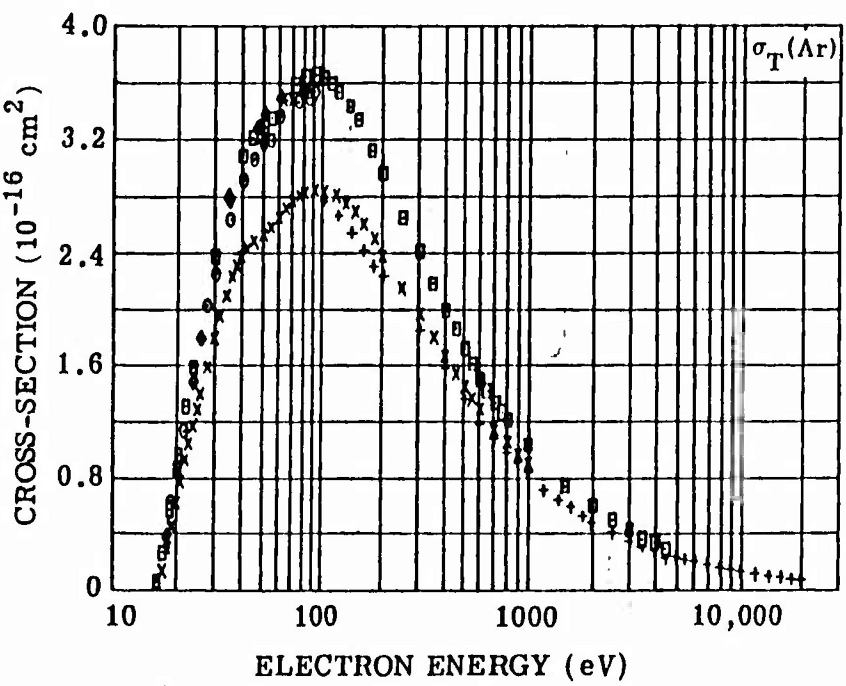

Figure B.3.a-13. (Source: R-14, Figure 10)

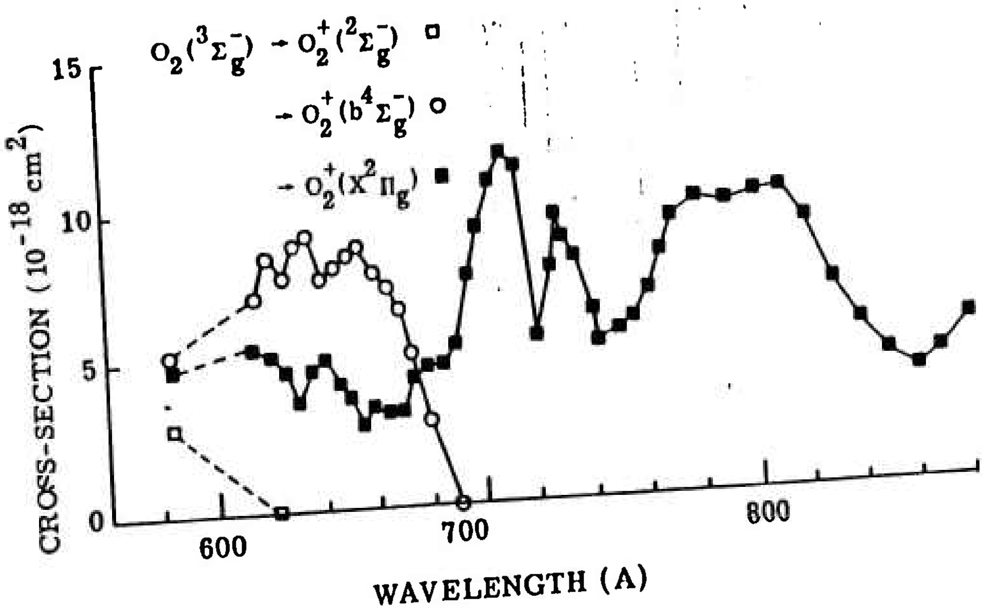

Figure B.3.a-14. Oxygen partial cross-sections for molecular ions. (Source: R-12, Figure 5)

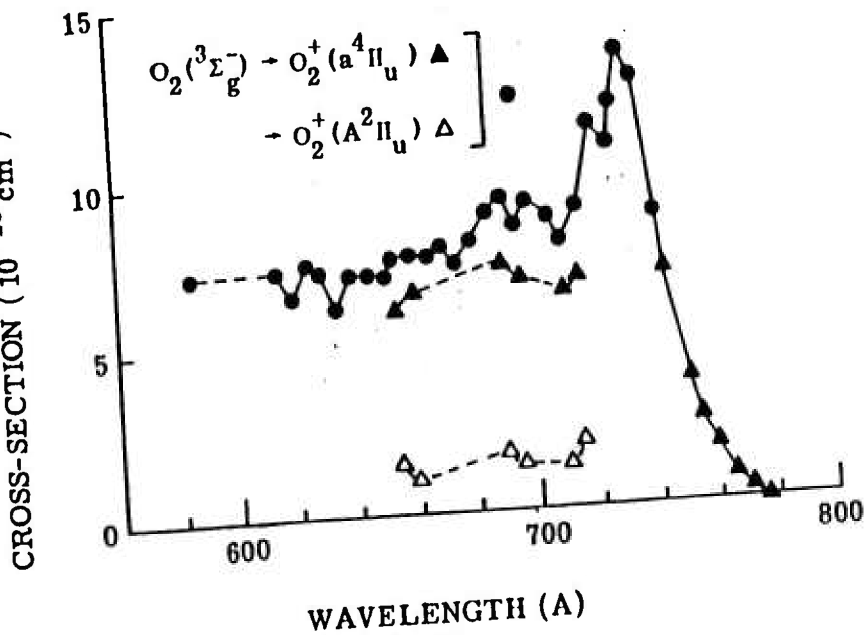

Figure B.3.a-15. Oxygen partial cross-sections for molecular ions. (Source: R-12, Figure 6)

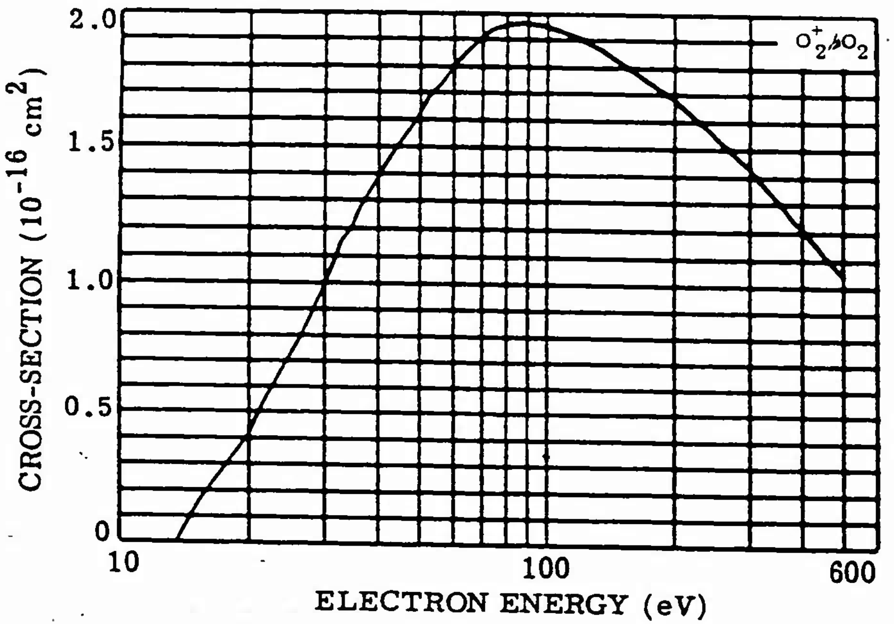

Figure B.3.a-16. (Source: R-14, Figure 46)

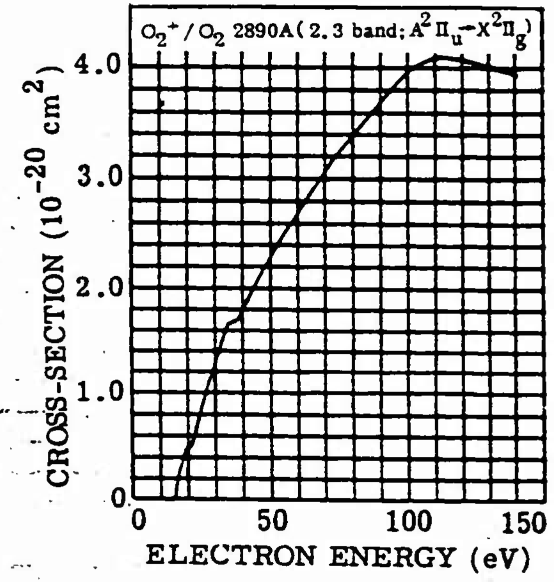

Figure B.3.a-17. (Source: R-14, Figure 47)

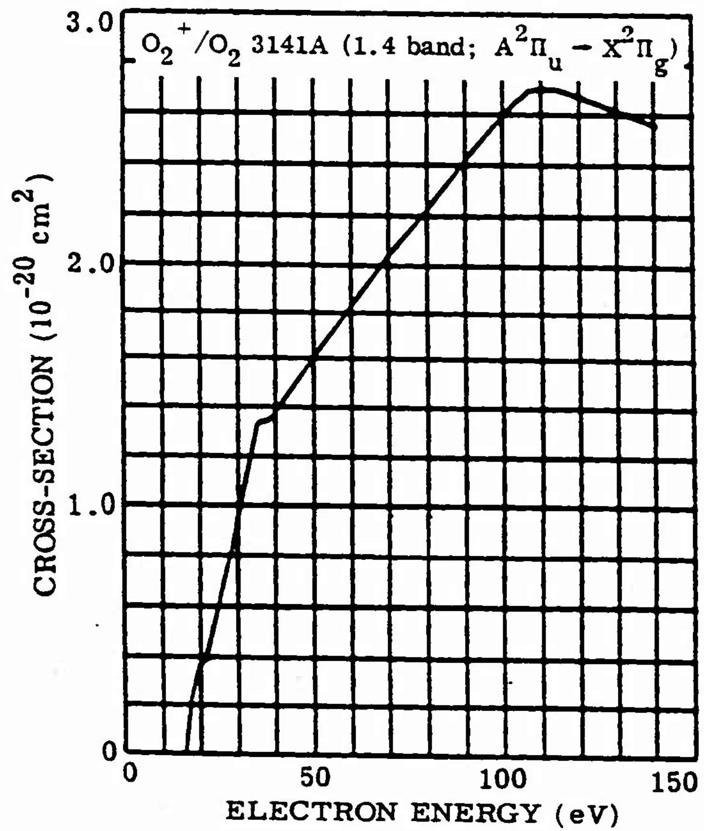

Figure B.3.a-18. (Source: R-14, Figure 48)

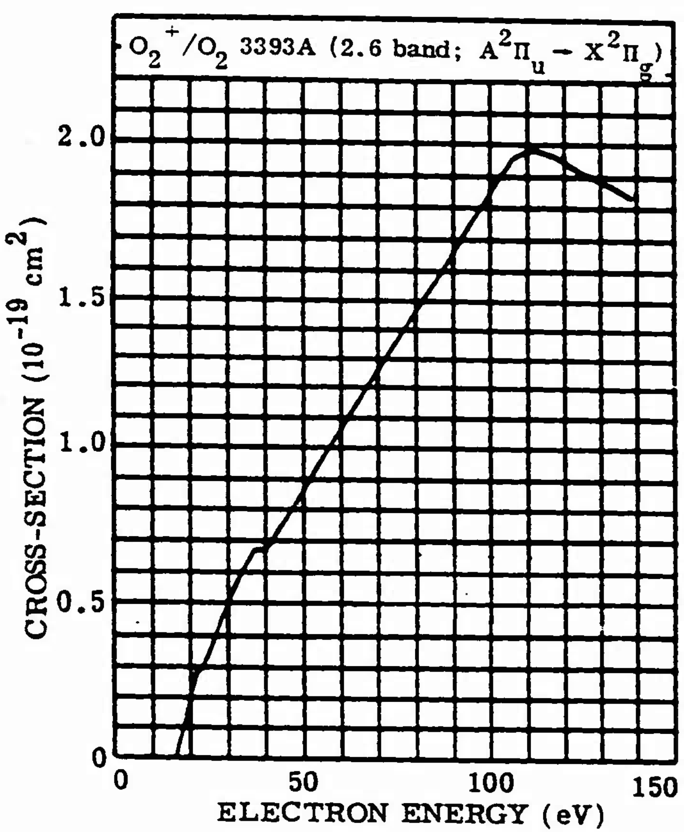

Figure B.3.a-19. (Source: R-14, Figure 49)

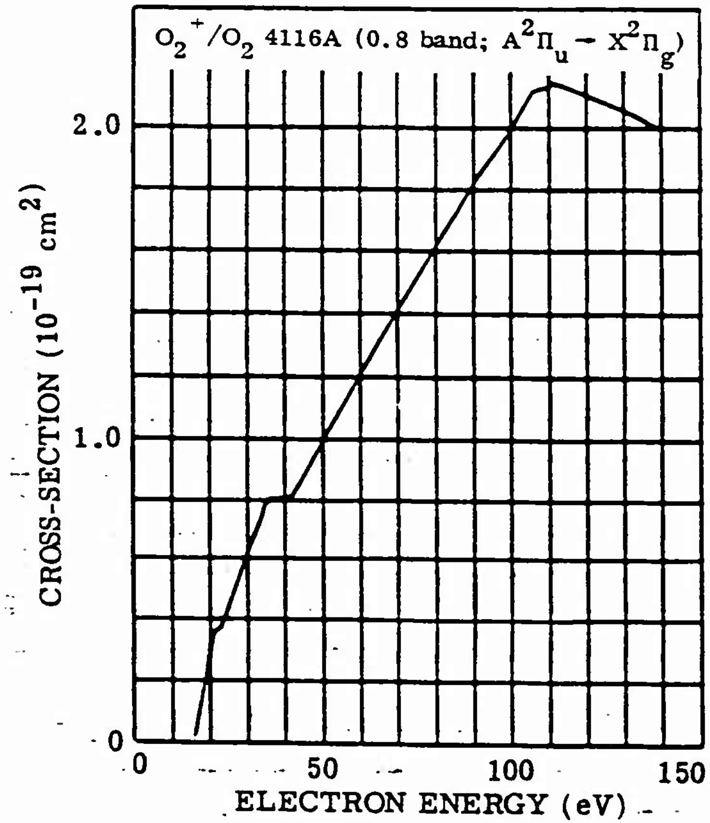

Figure B.3.a-20. (Source: R-14, Figure 50)

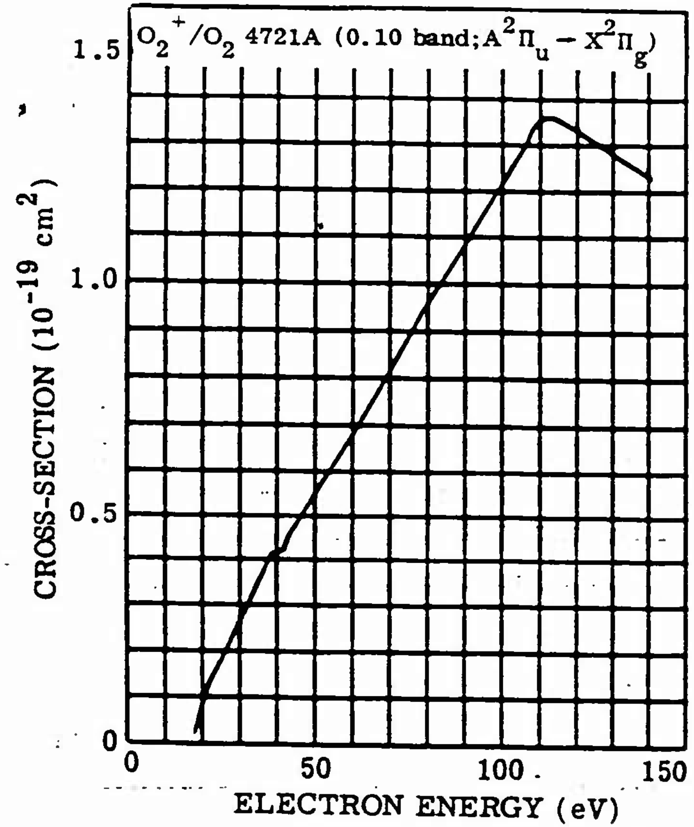

Figure B.3.a-21. (Source: R-14, Figure 51)

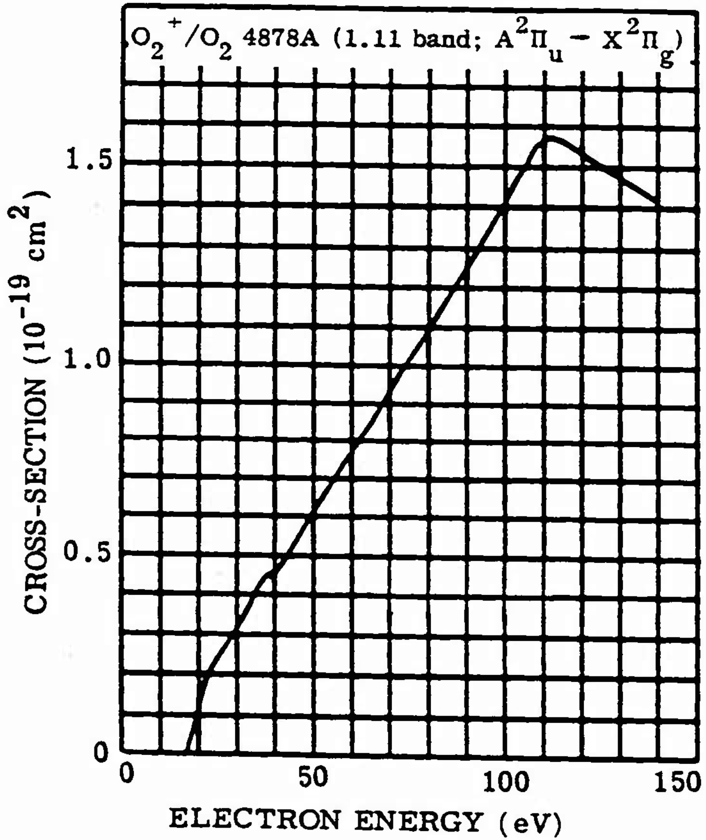

Figure B.3.a-22. (Source: R-14, Figure 52)

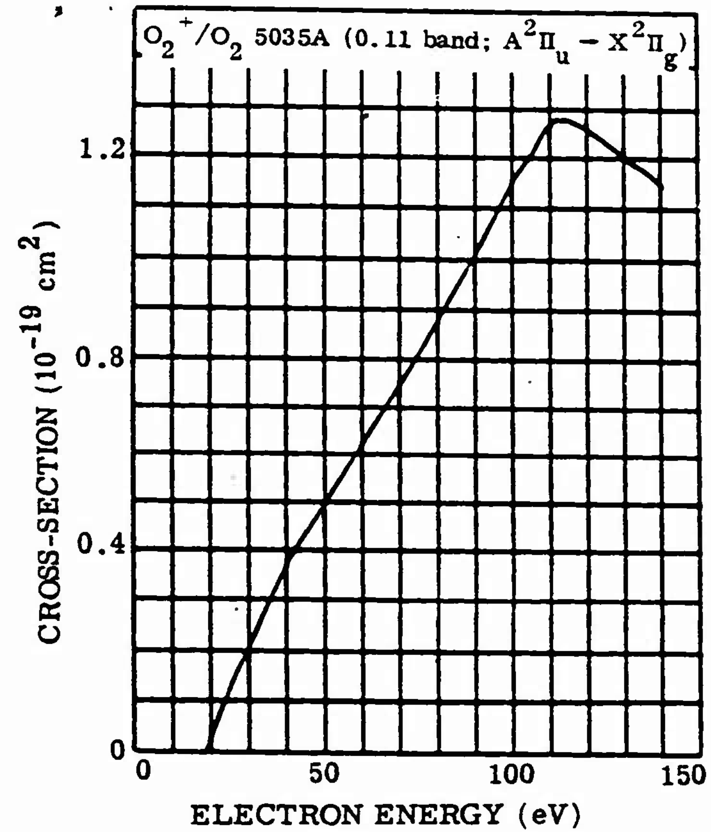

Figure B.3.a-23. (Source: R-14, Figure 53)

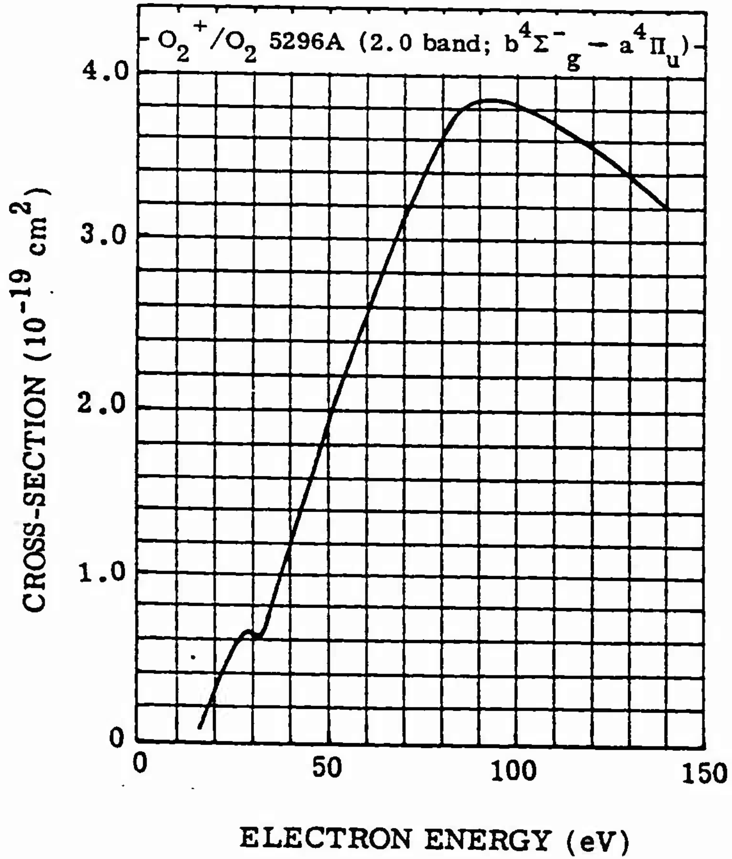

Figure B.3.a-24. (Source: R-14, Figure 54)

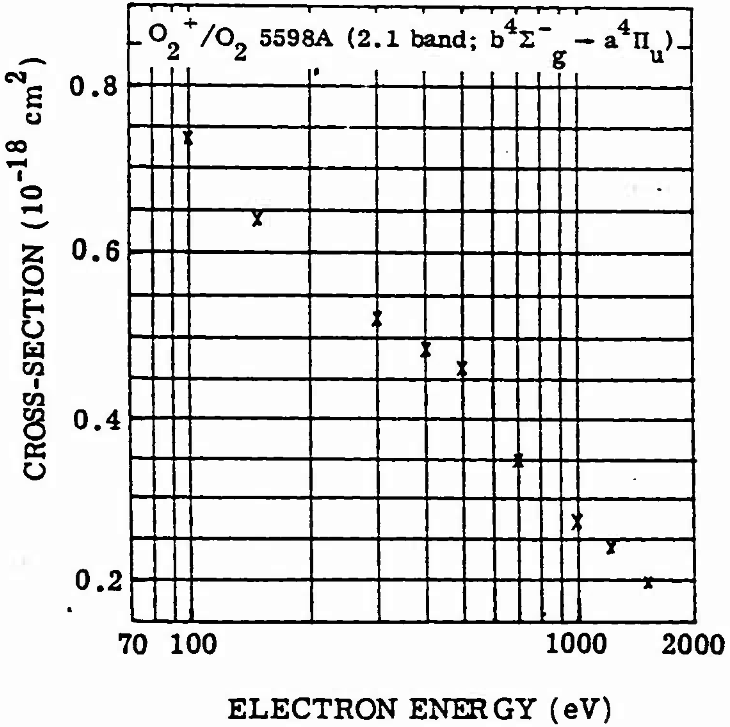

Figure B.3.a-25. (Source: R-14, Figure 55)

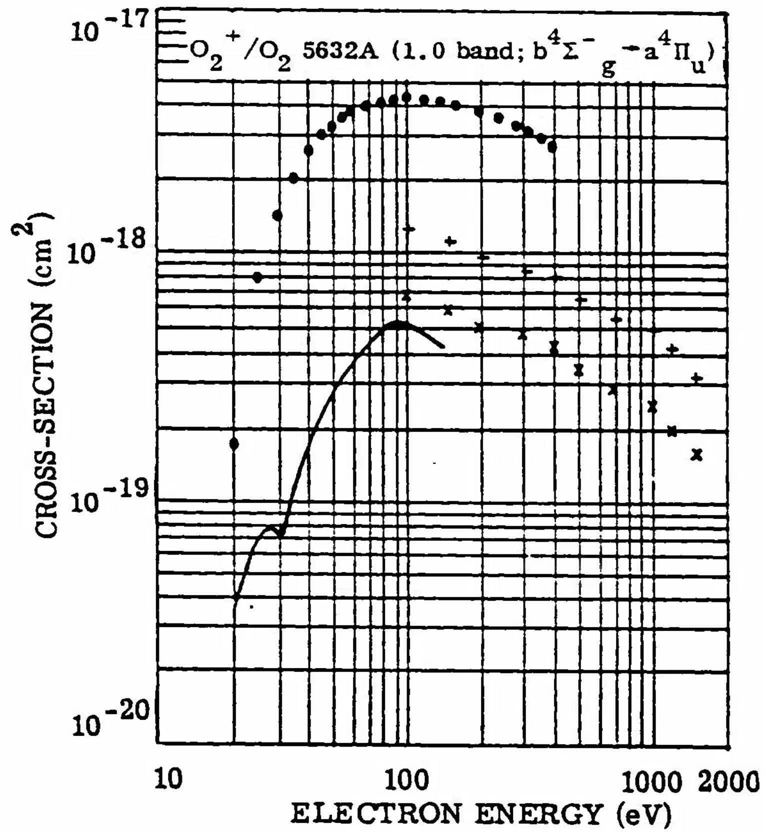

Figure B.3.a-26. (Source: R-14, Figure 56)

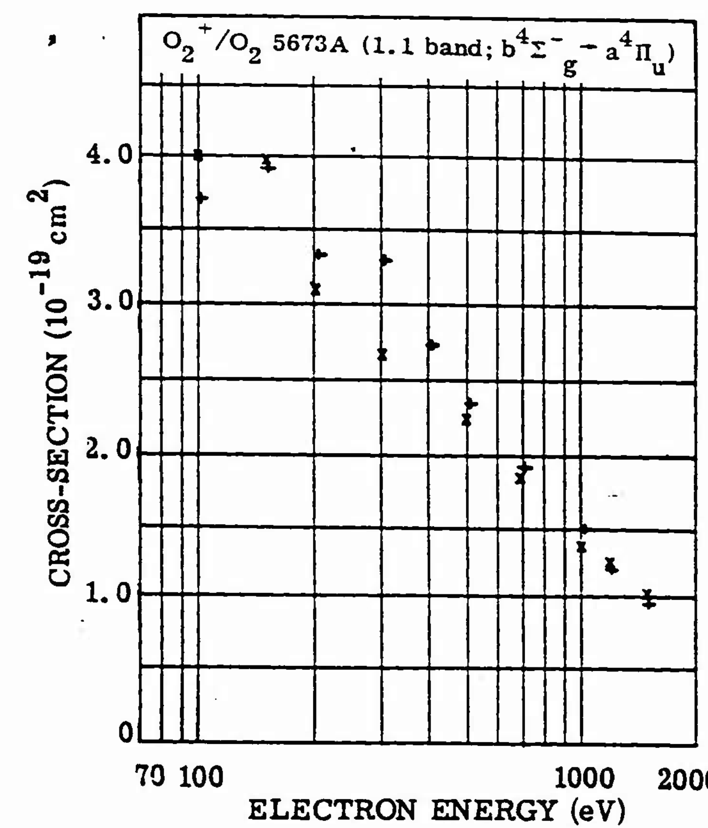

Figure B.3.a-27. (Source: R-14, Figure 57)

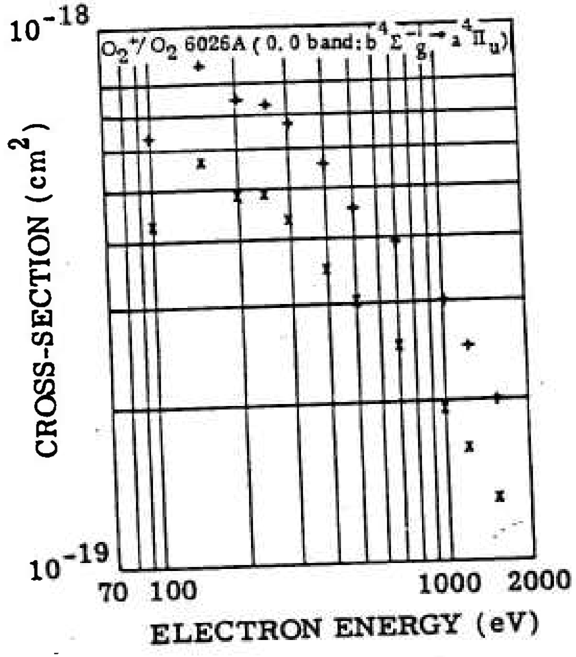

Figure B.3.a-28. (Source: R-14, Figure 58)

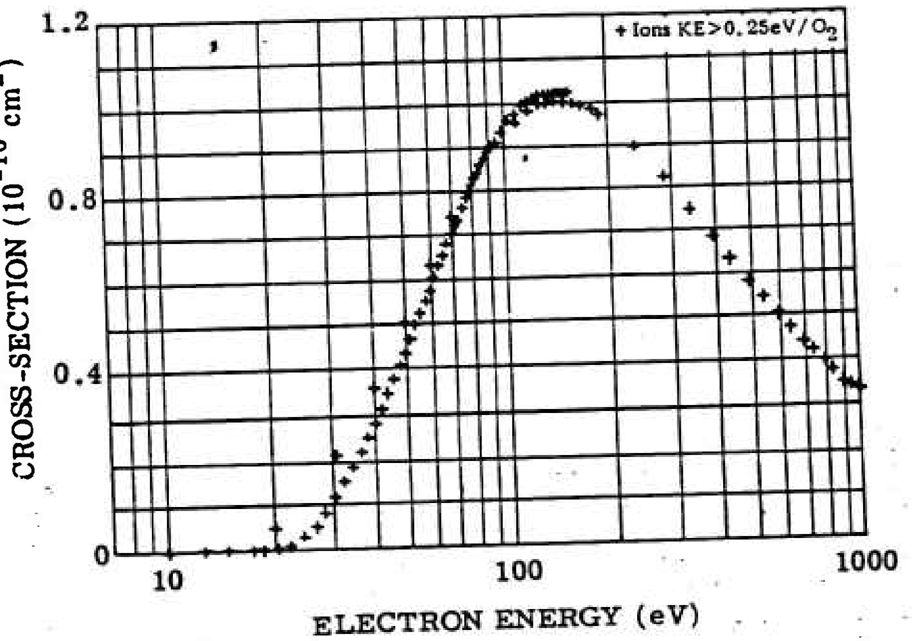

Figure B.3.a-29. (Source: R-14, Figure 59)

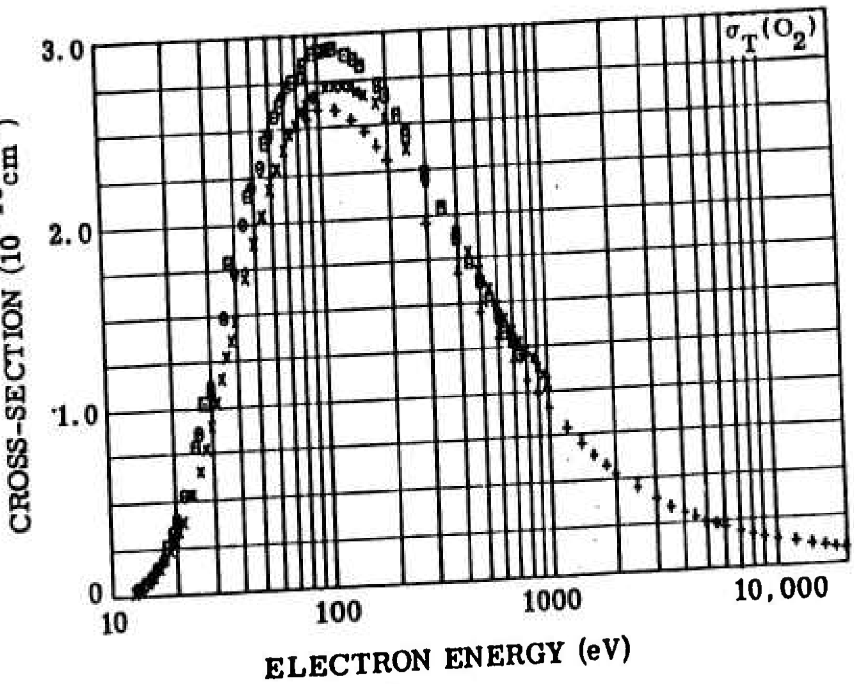

Figure B.3.a-30. (Source: R-14, Figure 45)

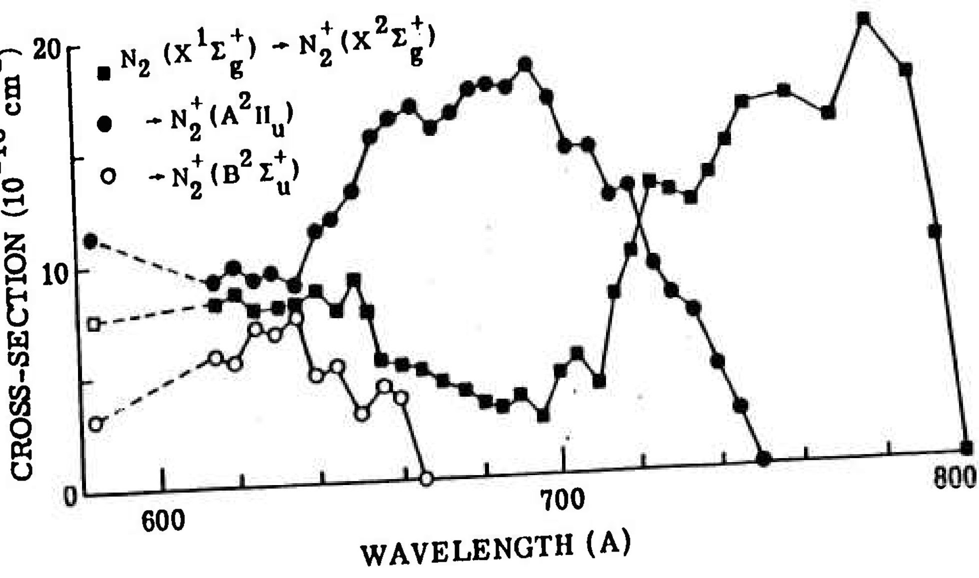

Figure B.3.a-31. Nitrogen partial cross-sections for molecular ions. (Source: R-12, Figure 7)

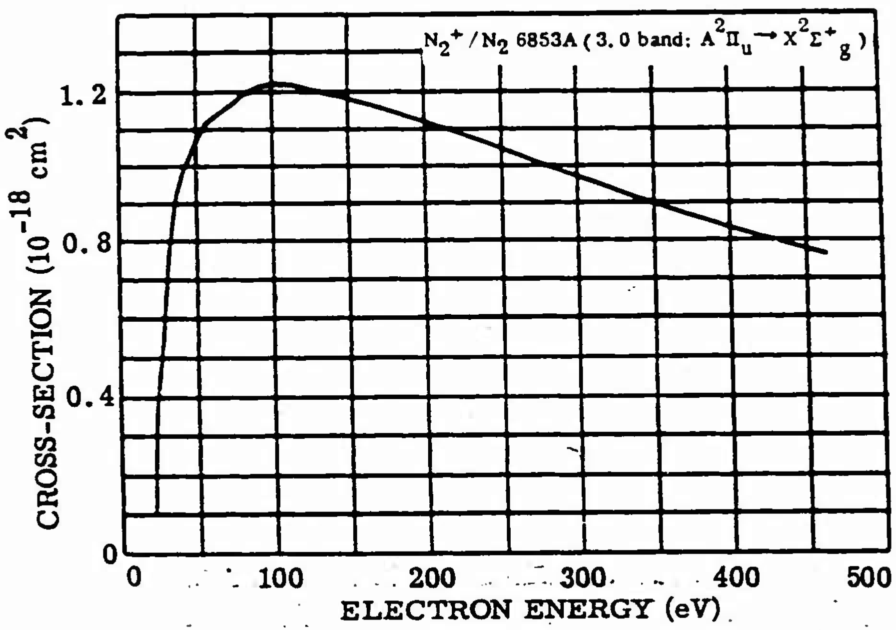

Figure B.3.a-32. (Source: R-14, Figure 30)

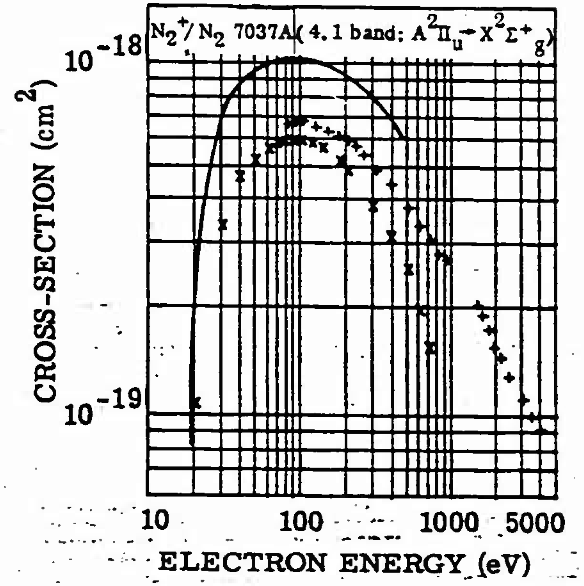

Figure B.3.a-33. (Source: R-14, Figure 31)

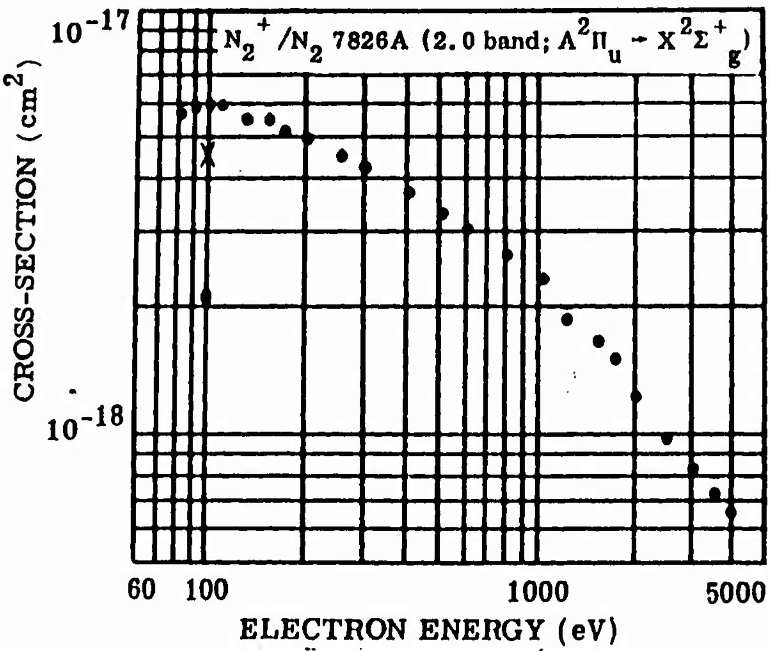

Figure B.3.a-34. (Source: R-14, Figure 32)

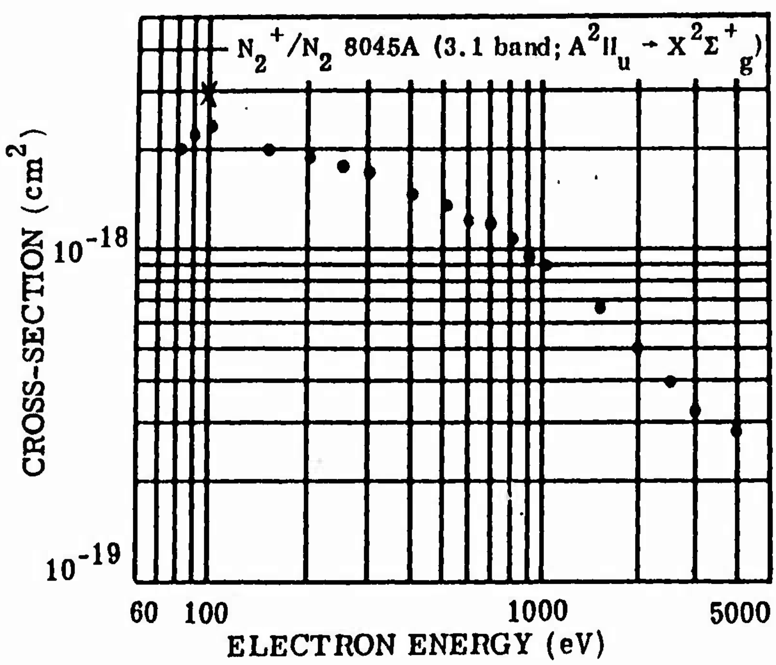

Figure B.3.a-35. (Source: R-14, Figure 33)

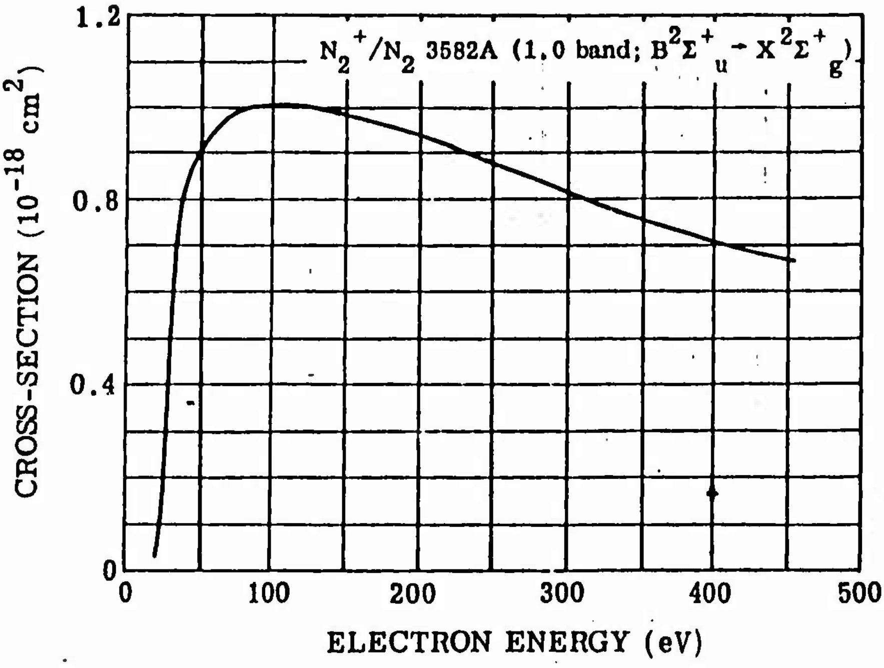

Figure B.3.a-36. (Source: R-14, Figure 34)

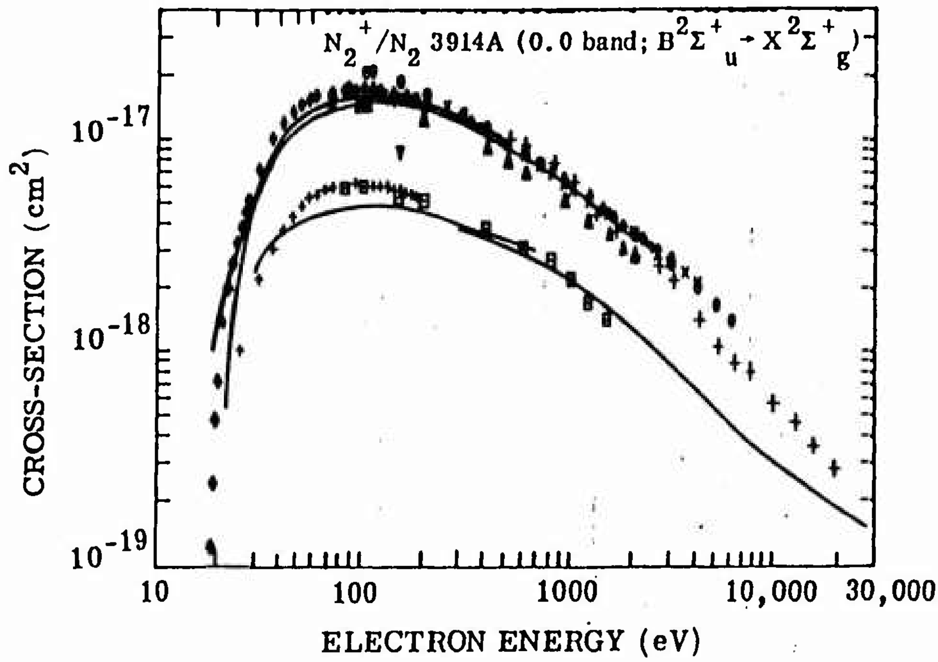

Figure B.3.a-37. (Source: R-14, Figure 35)

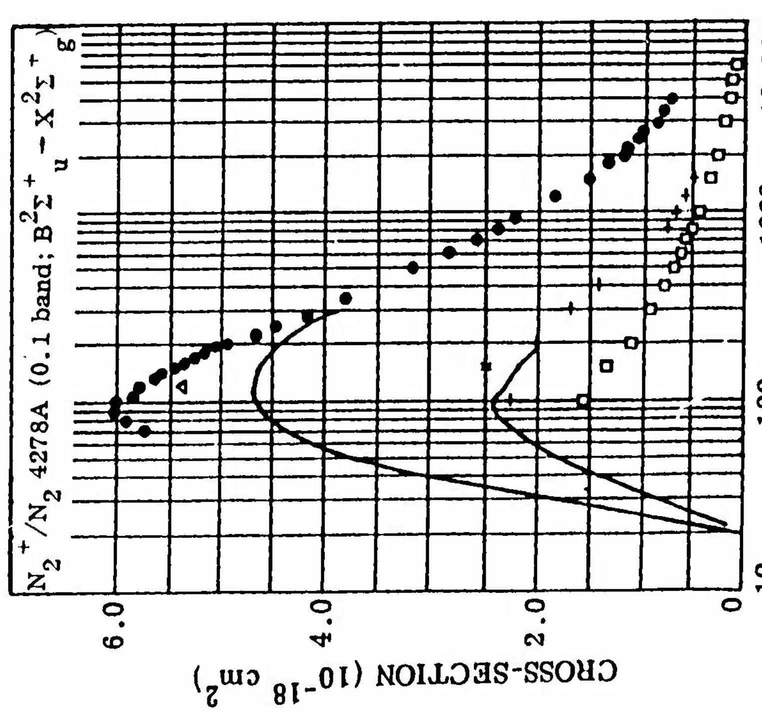

Figure B.3.a-38. (Source: R-14, Figure 36)

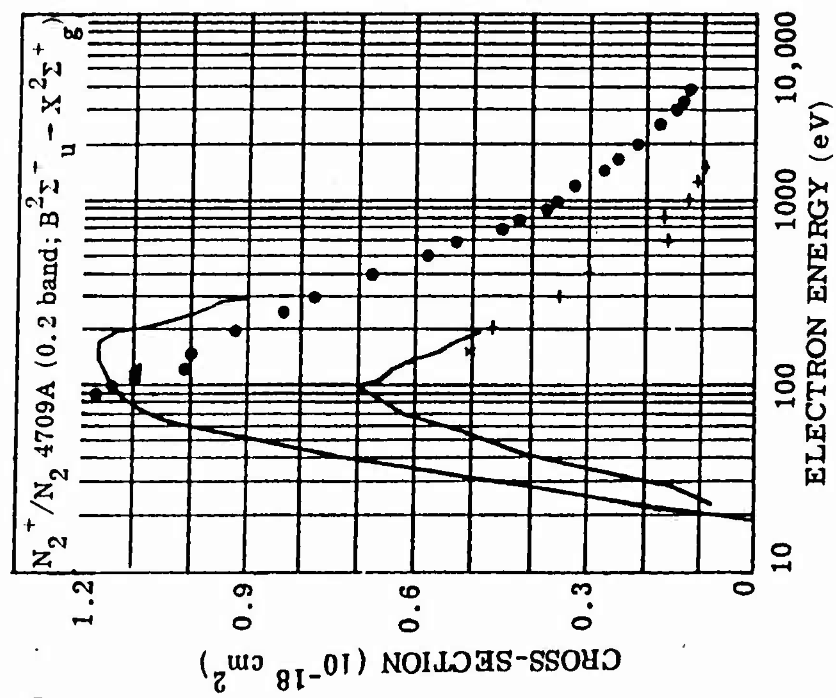

Figure B.3.a-39. (Source: R-14, Figure 37)

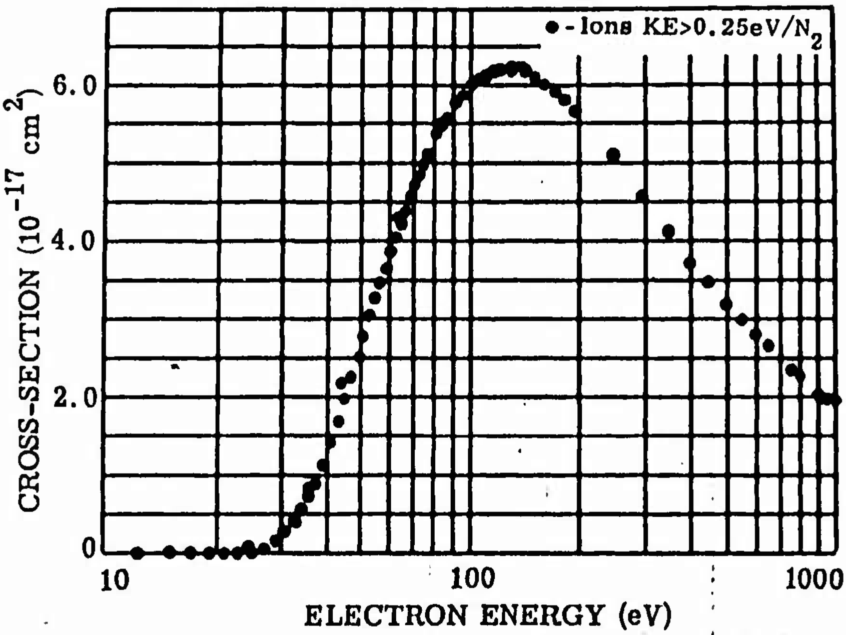

Figure B.3.a-40. (Source: R-14, Figure 38)

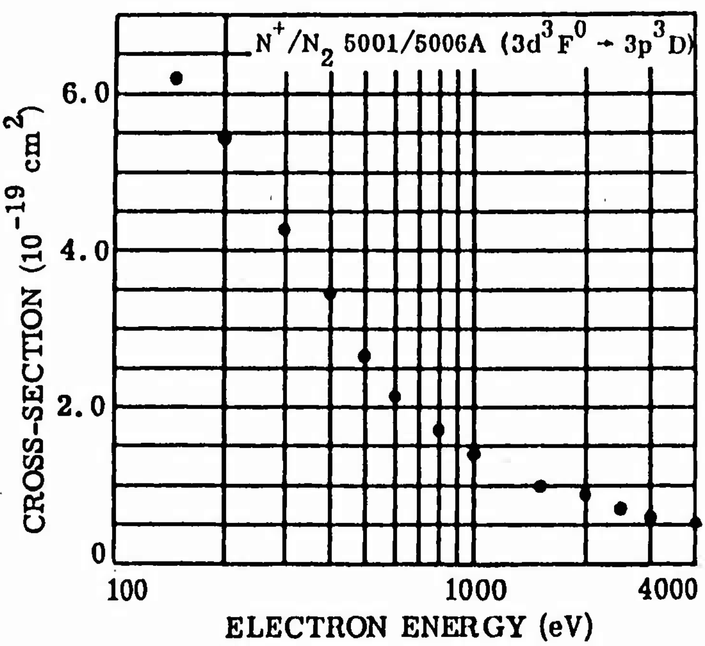

Figure B.3.a-41. (Source: R-14, Figure 39)

Table B.3.a-1. Effective dissociative ionization cross-sections of N_2. (Source: R-14, Table 3)

N^+/N_2

Wavelength (A)	Transition	E (eV)	$\sigma(10^{-18}\ cm^2)$
623.9	$3s'\ ^5P \rightarrow 2p'\ ^5S$	100.	0.23
645.6	$2p'\ ^3S \rightarrow 2p\ ^3P$	100.	0.25
671.4	$2s\ ^3P \rightarrow 2p\ ^3P$	100.	4.5
746.4	$3s'P \rightarrow 2p\ ^1D$	100.	3.2
746.4	$2p'\ ^1P \rightarrow 2p\ ^1S$	100.	3.2
775.1	$2p'\ ^1D \rightarrow 2p\ ^1D$	100.	2.3
918	$2p'\ ^3P \rightarrow 2p\ ^3P$	100.	11.9
1084.4	$2p'\ ^3D \rightarrow 2p\ ^3P$	100.	20.4
5667	$3p\ ^3D_2 \rightarrow 3s\ ^3P_1$	500.	0.0886
5680	$3p\ ^3D_3 \rightarrow 3s\ ^3P_2$	500.	0.231

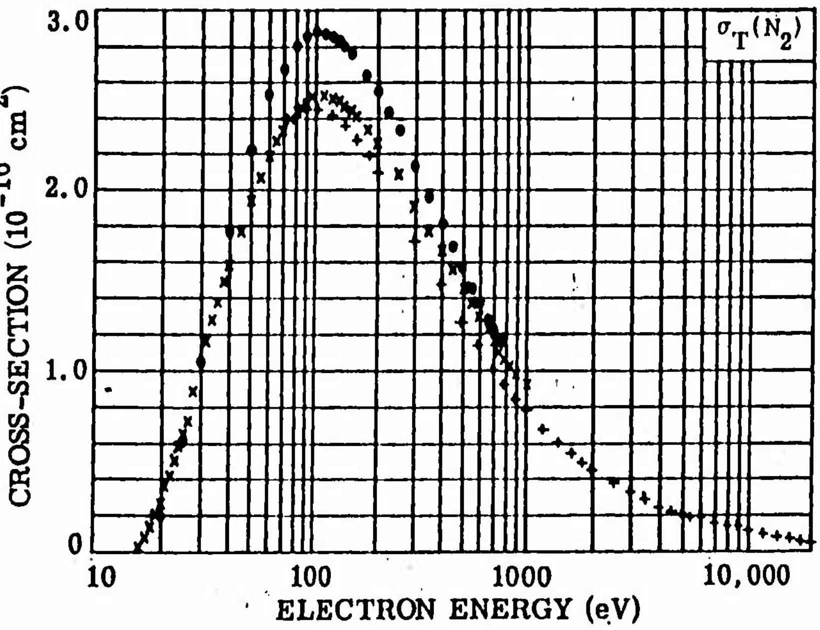

Figure B.3.a-42. (Source: R-14, Figure 29)

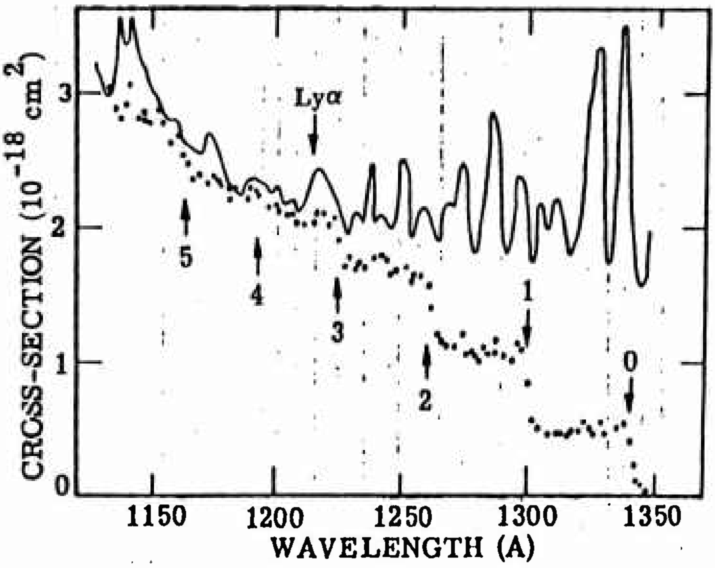

Figure B.3.a-43. Nitric oxide cross-sections. Solid curve is absorption cross-section; points are ionization cross-section. (Source: R-12, Figure 13)

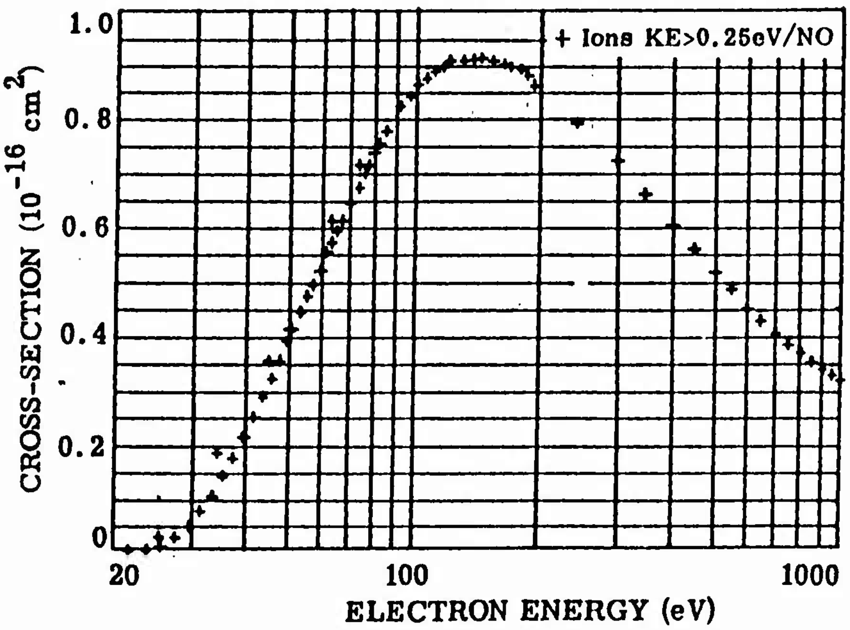

Figure B.3.a-44. (Source: R-14, Figure 43)

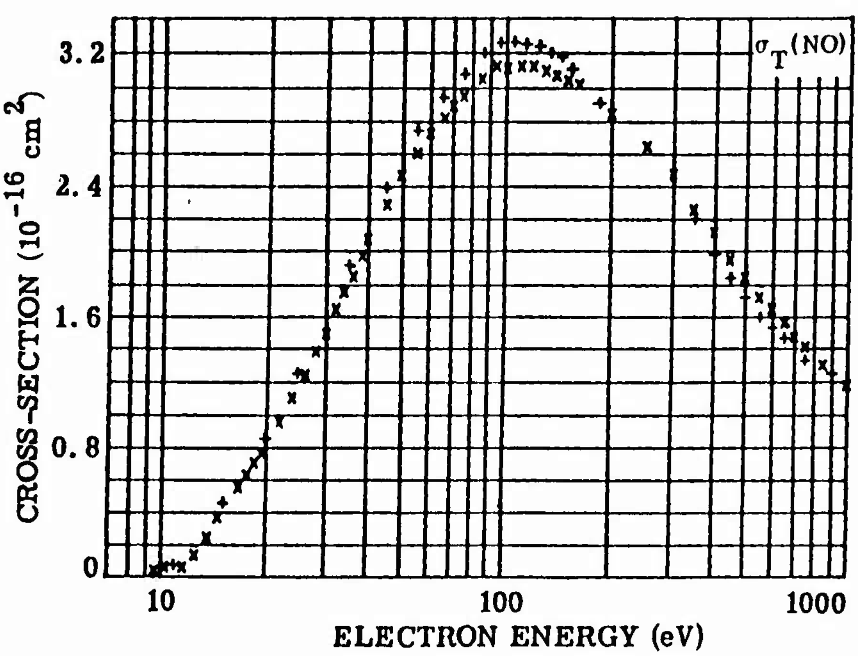

Figure B.3.a-45. (Source: R-14, Figure 42)

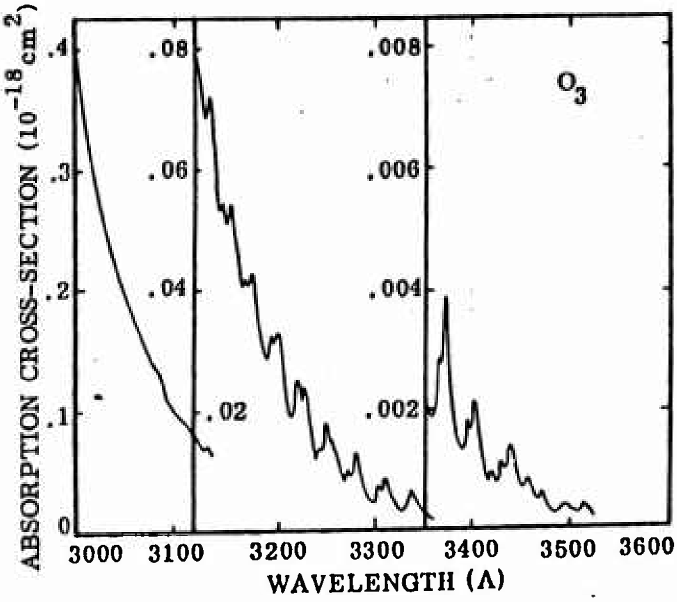

Figure B.3.a-46. Ozone cross-sections. Wavelength 3000-3600 A. (Source: R-12, Figure 14)

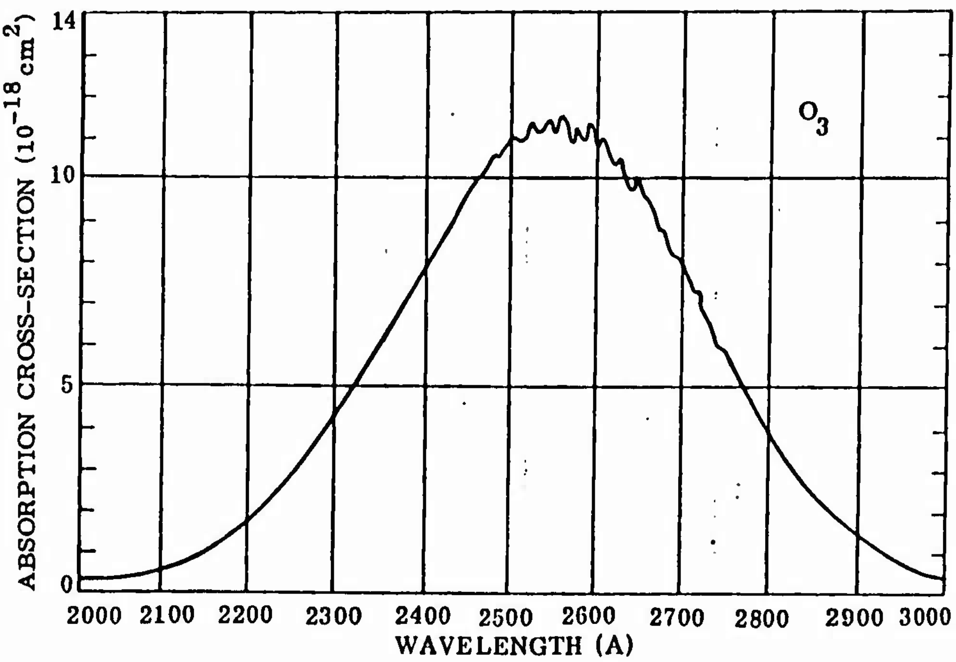

Figure B.3.a-47. Ozone cross-sections. Wavelength 2000-3000 A. (Source: R-12, Figure 15)

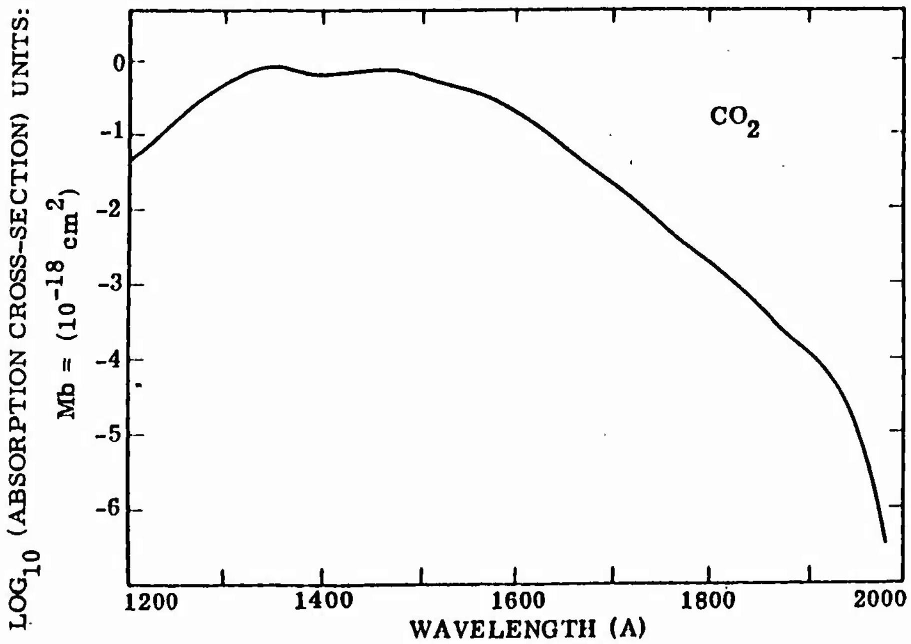

Figure B.3.a-48. Carbon dioxide cross-sections. (Source: R-12, Figure 16)

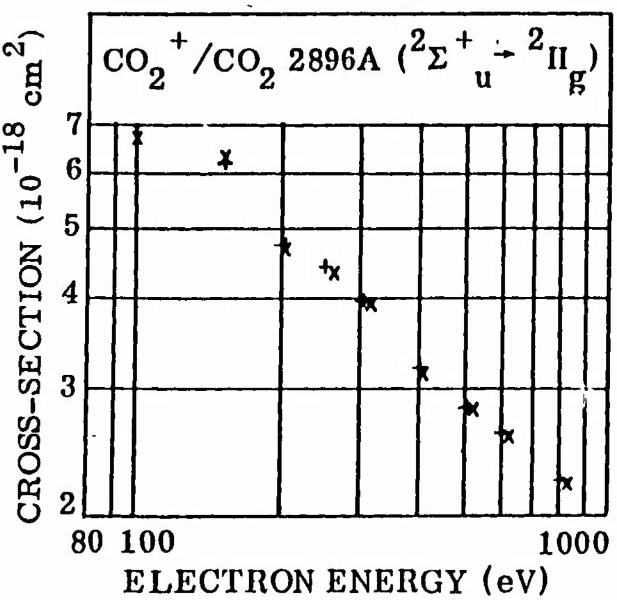

Figure B.3.a-49. (Source: R-14, Figure 67)

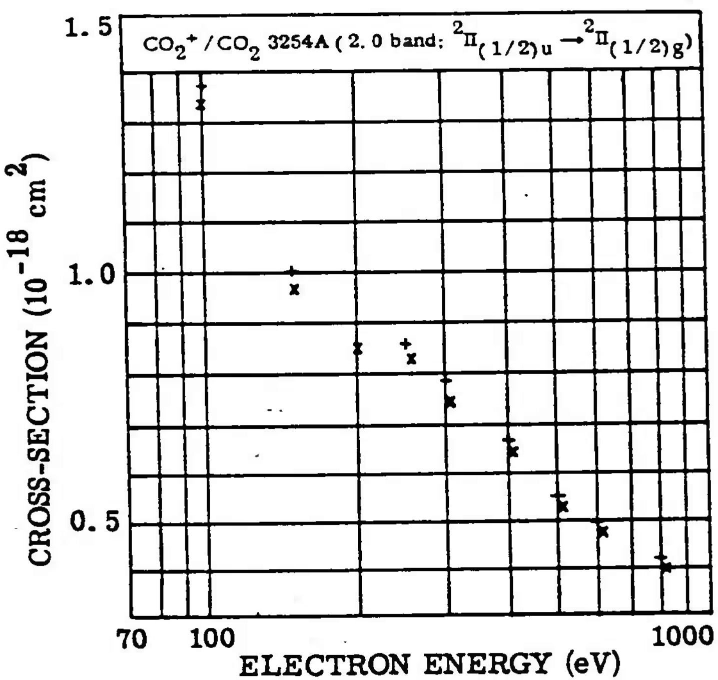

Figure B.3.a-50. (Source: R-14, Figure 68)

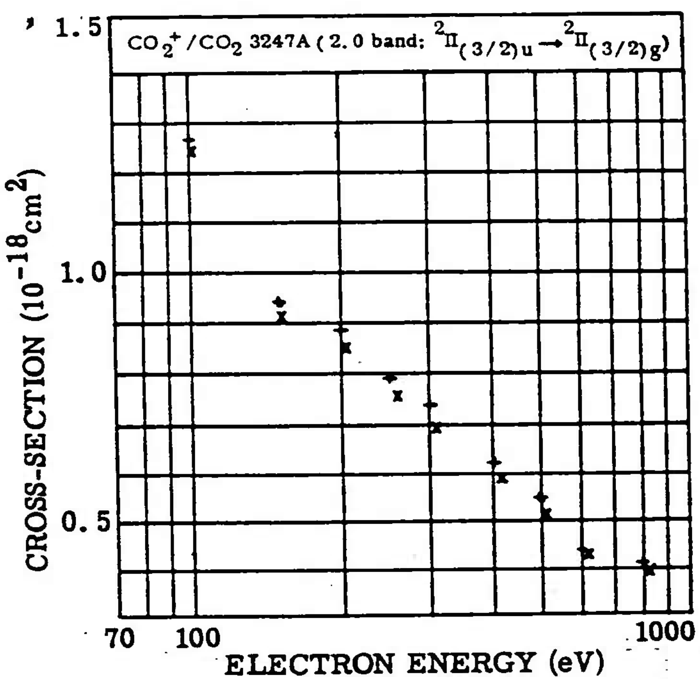

Figure B.3.a-51. (Source: R-14, Figure 69)

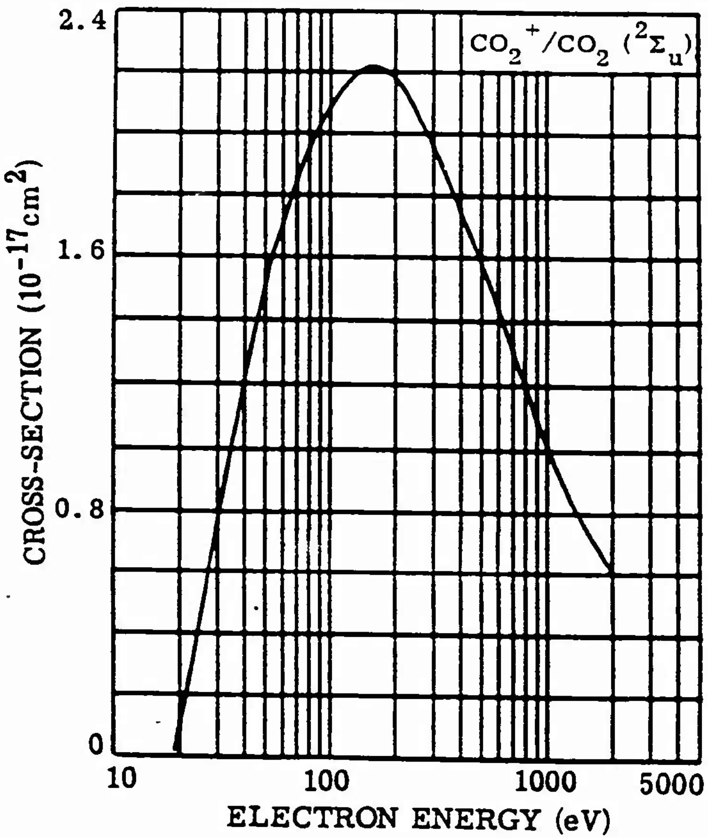

Figure B.3.a-52. (Source: R-14, Figure 70)

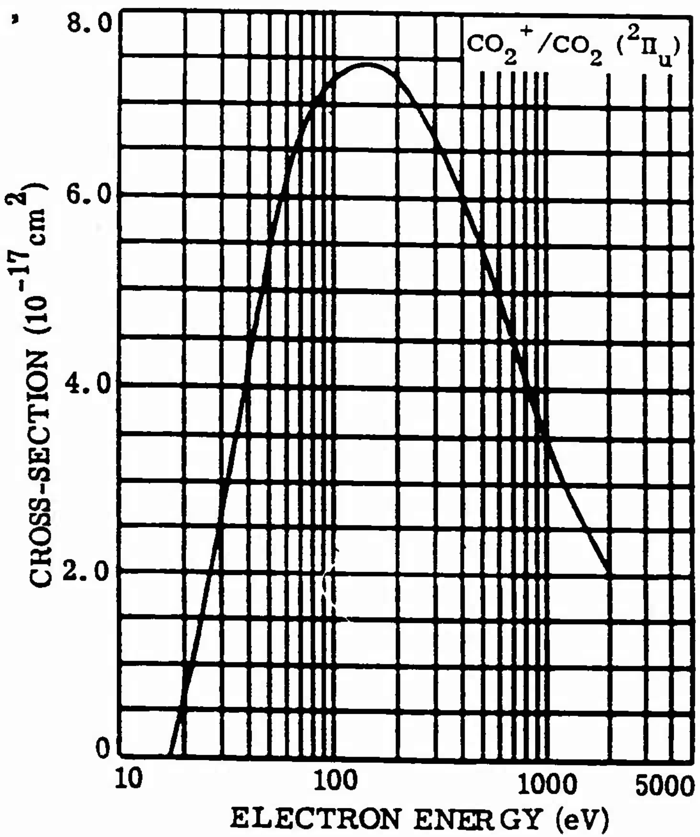

Figure B.3.a-53. (Source: R-14, Figure 71)

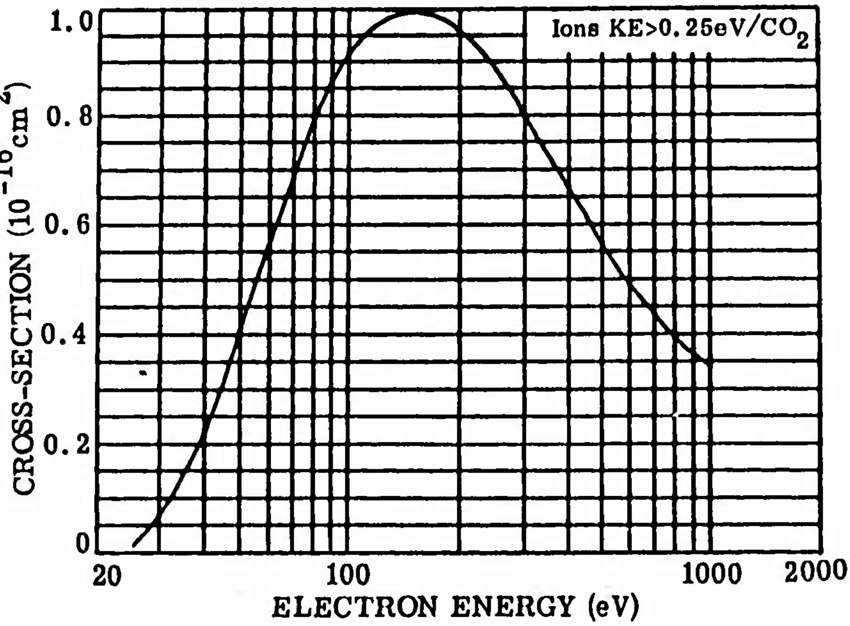

Figure B.3.a-54. (Source: R-14, Figure 72)

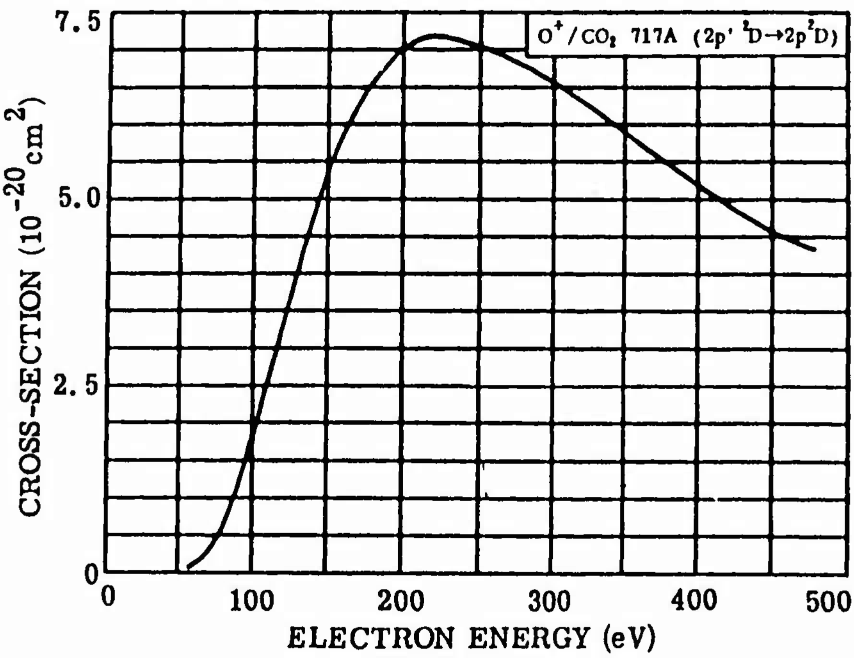

Figure B.3.a-55. (Source: R-14, Figure 73)

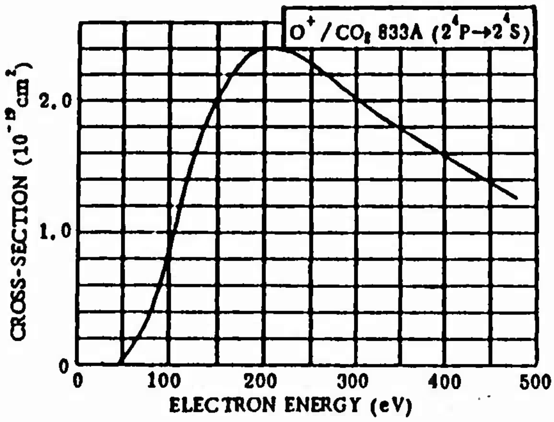

Figure B.3.a-56. (Source: R-14, Figure 74)

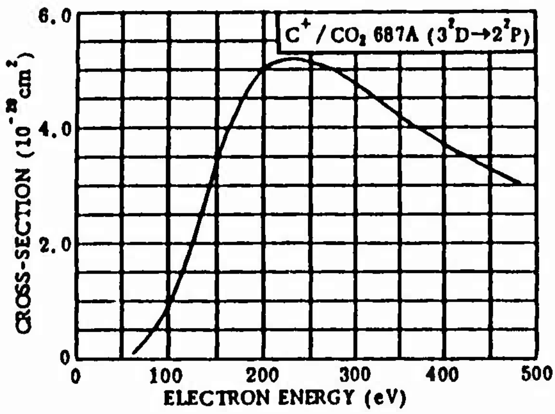

Figure B.3.a-57. (Source: R-14, Figure 75)

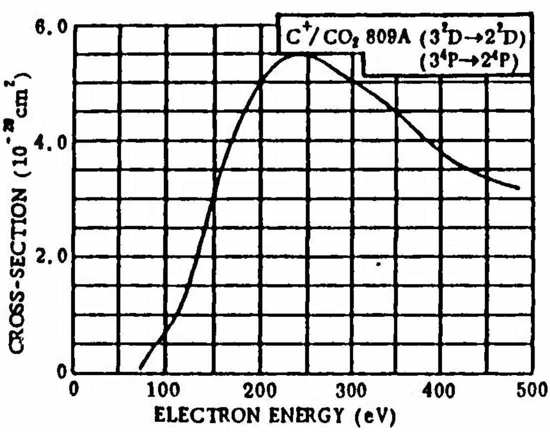

Figure B.3.a-58. (Source: R-14, Figure 76)

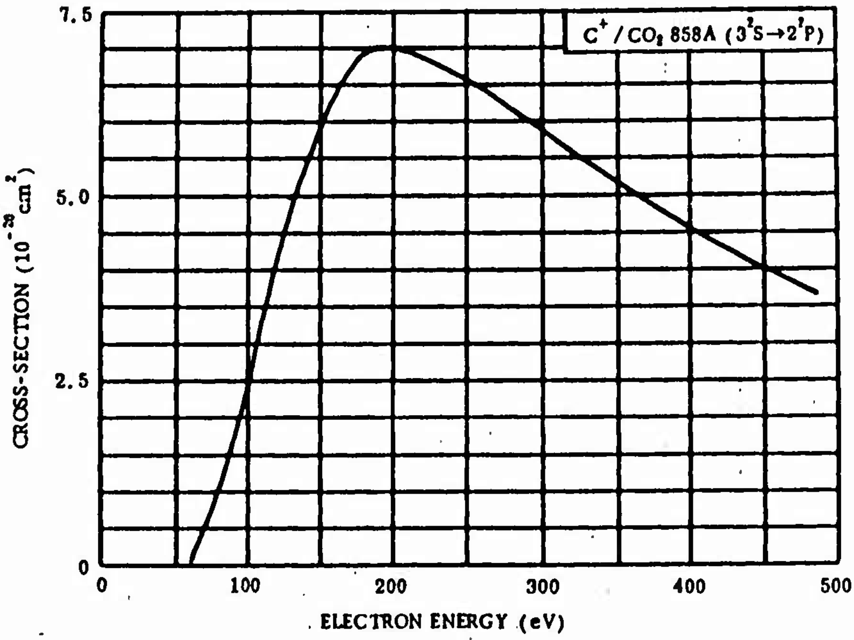

Figure B.3.a-59. (Source: R-14, Figure 77)

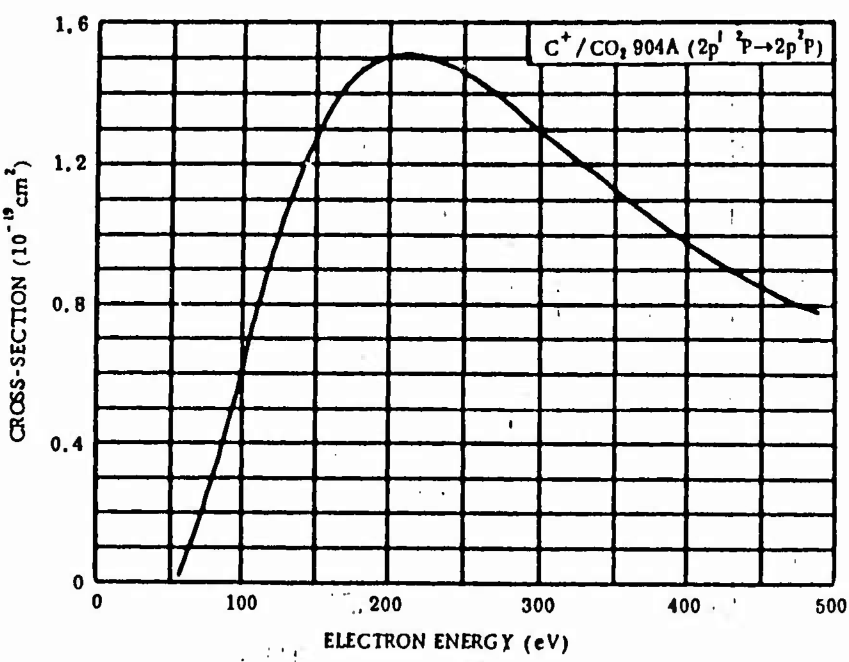

Figure B.3.a-60. (Source: R-14, Figure 78)

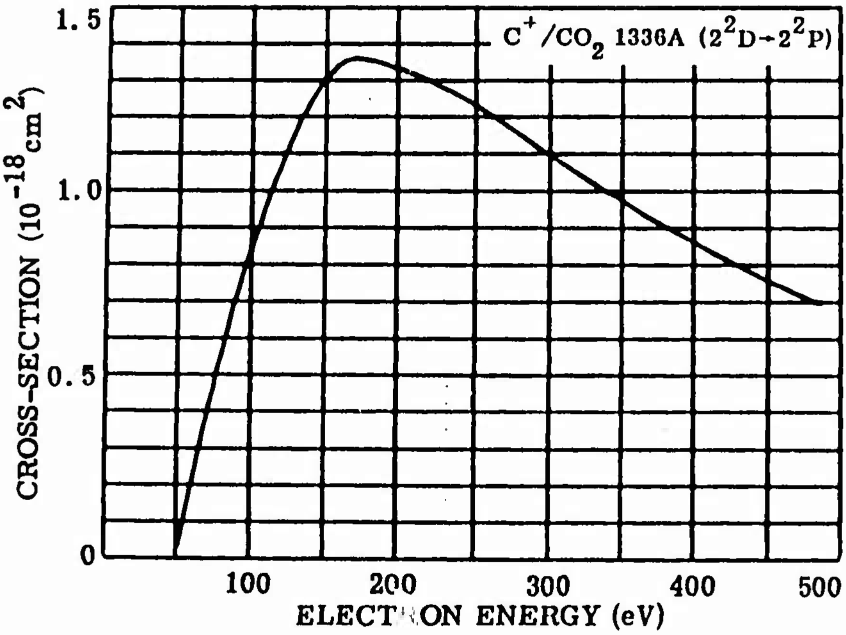

Figure B.3.a-61. (Source: R-14, Figure 79)

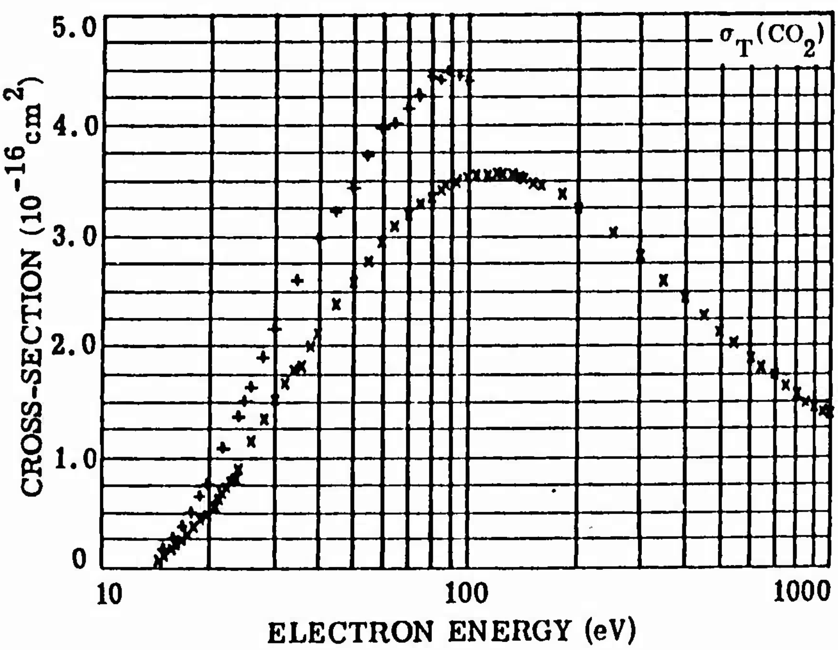

Figure B.3.a-62. (Source: R-14, Figure 66)

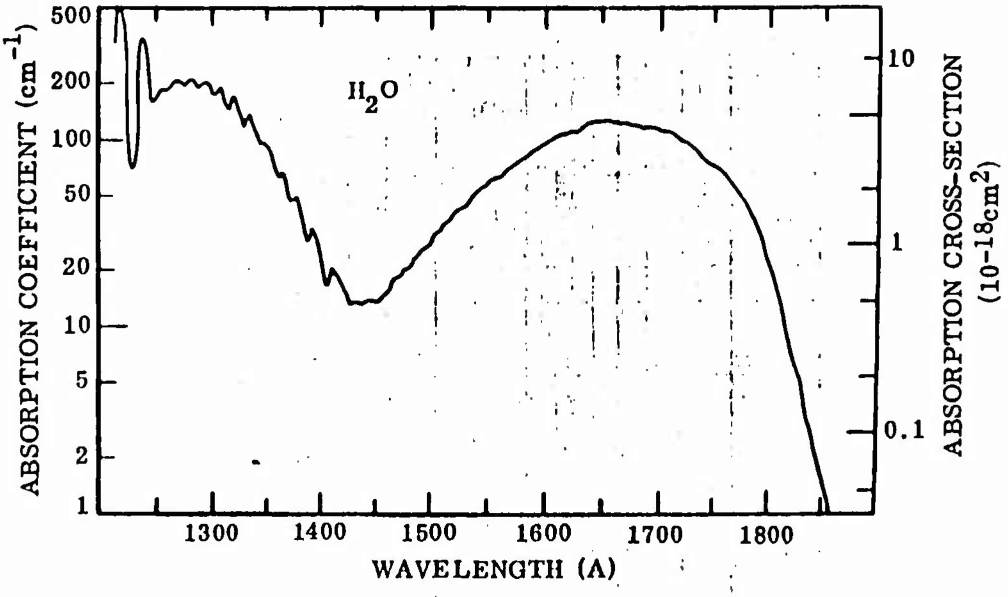

Figure B.3.a-63. Water vapor cross-sections.
(Source: R-12, Figure 17)

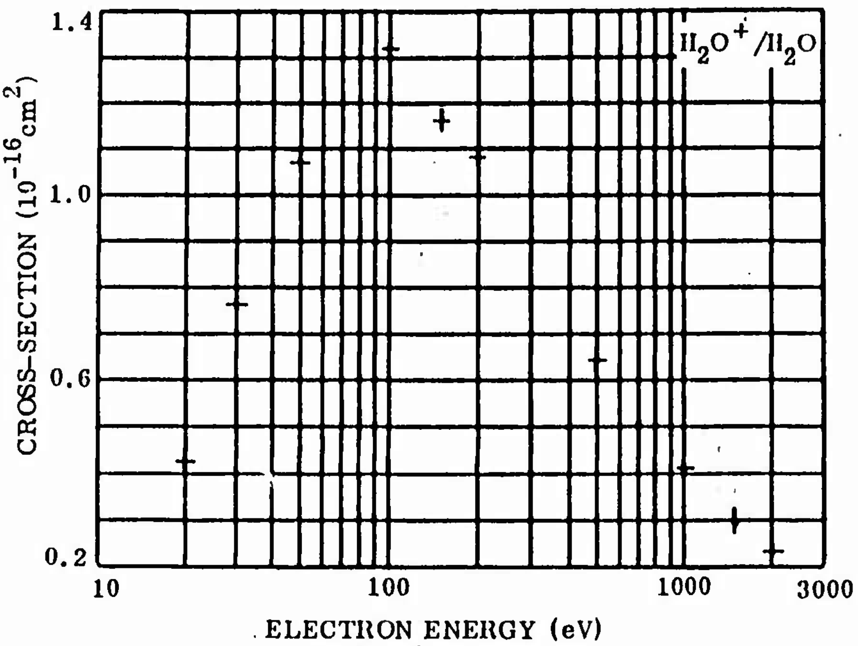

Figure B.3.a-64. (Source: R-14, Figure 63)

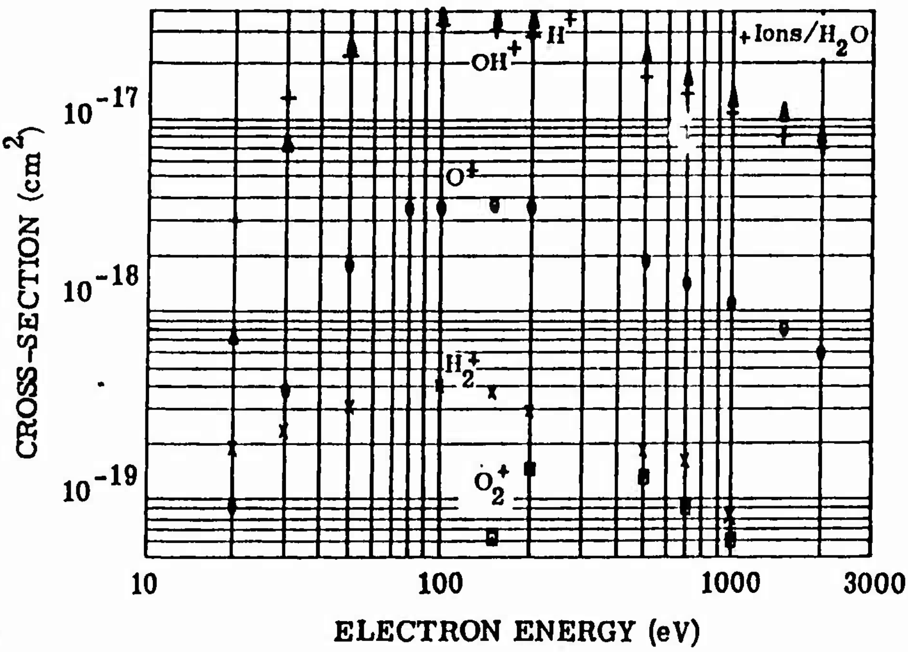

Figure B.3.a-65. (Source: R-14, Figure 64)

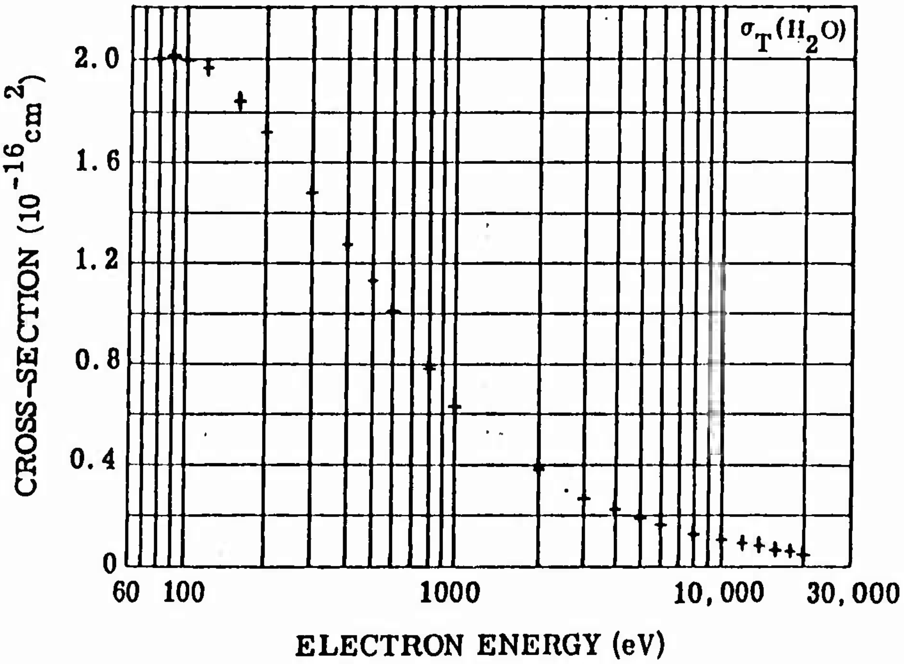

Figure B.3.a-66. (Source: R-14, Figure 62)

Table B.3.a-2. Absorption and ionization cross-sections of O_2, N_2, and O at solar lines. Cross-sections in megabarns ($10^{-18} cm^2$). (Source: R-12, Table 3)

Solar Line λ (A)	Class.	O_2		N_2		O
		σ	σ_i	σ	σ_i	$\sigma = \sigma_i$
1215.7	H Ly α	0.010	0	$<6x10^{-5}$	0	0
1206.5	Si III	15	0	~0	0	0
1175.5	C III	1.3	0	-	0	0
1085.7	N II	2	0	-	0	0
1037.6	O VI	0.78	0	$<7x10^{-4}$	0	0
1031.9	O VI	1.04	0	$<7x10^{-4}$	0	0
1025.7	H Ly β	1.58	.98	$<10^{-3}$	0	
991.6	N III	1.75	1.21	1.9	0	0
989.8	N III	1.4	0.95	1.1	0	
977.0	C III	4.0	2.5	0.7	0	0
972.5	H Ly γ	32	25	360	0	0
949.7	H Ly	6.3	4	5.2	0	0
937.8	H Ly	5.0	3	10	0	
930.7	H Ly	26	17	4.8	0	
904.0	C II	11	6.3	6.3	0	3.0
835.3	O III	10	3.7	20	0	2.6
835.1	O III	10	3.7	41	0	2.6
834.5	O II	11	4.0	7.5	0	2.6
833.7	O III	13	5.1	6	0	2.6
833.3	O II	13	5	2.3	0	2.6
832.9	O III	26	10	7	0	2.6
832.8	O II	26	10	2.1	0	2.6
790.2	O IV	28	10	22	10	2.9
790.1	O IV	28	10	28	11	2.9
787.7	O IV	24	13	10	8	2.9
780.3	Ne VIII	28	11	19	-	2.9

Table B.3.a-2. (Continued)

Solar Line λ (A)	Class.	O_2		N_2		O
		σ	σ_i	σ	σ_i	$\sigma = \sigma_i$
770.4	Ne VIII	18	11	15	-	7
765.1	N IV	23	12	67	51	3.0
760.4	O V	20	10	40	22	2.9
703.8	O III	26	23	22	20	6.5
702.3	O III	24	21	24	22	6.5
686.3	N III	22	22	25	24	6.5
685.8	N III	18	18	26	25	6.5
685.5	N III	18	18	25	24	6.5
685.0	N III	26	26	25	24	6.5
629.7	O V	30	29	23	23	9.0
625.0	Mg X	25	24	24	23	9.0
610.0	Mg X	27	25	24	24	9.0
599.6	O III	28	27	23	22	9.0
584.3	He I	23	23	23	23	9.5
555.3	O IV	26	25	25	24	9.5
554.5	O IV	26	26	25	23	9.5
554.1	O IV	26	25	25	24	9.5
553.3	O IV	26	24	25	24	9.5
537.0	He I	21	21	25	24	9.3
525.8	O III	25	24	26	26	9.3
522.2	He I	21	21	24	23	9.3
508.2	O III	24	23	22	22	9.3
507.7 507.4	O III	23	22	24	24	9.3
435.0	O III	21	21	24	24	9
430.2 430.0 429.9	O II	18	18	21	21	9
303.8	He I	17	17	12	12	8.5

Table B.3.a-3. Absorption cross-sections at wavelengths less than 304A. Cross-sections in megabarns (10^{-18} cm^2). (Source: R-12, Table 4)

Wavelength (A)	O_2	N_2	O
247.2	12.3	9.8	6.0
209.3	9.0	6.5	4.0
100.0	1.9	0.84	0.8
68.0	0.9	0.50	0.2
44.6	0.31	0.18	0.1
13.4	0.29	0.089	0.14
9.9	0.14	0.042	0.071

Table B.3.a-4. Molecular nitrogen, N_2: photon cross-sections for very strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 6a)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products σ_{i_X}	σ_{i_A}	σ_{i_B}	Neutral σ_N	Neutral Product
N_{II} #1							
1085.70	<0.1	0	0	0	0	<0.1	Excitation
1084.57	<0.1	0	0	0	0	<0.1	Excitation
1083.98	<0.1	0	0	0	0	<0.1	Excitation
1085.54	<0.1	0	0	0	0	<0.1	Excitation
O_{II} #1							
834.467	7.5	0	0	0	0	7.5	Excitation
833.332	2.3	0	0	0	0	2.3	Dissoc.
832.762	2.1	0	0	0	0	2.1	Dissoc.
N_{III} #1							
991.579	2	0	0	0	0	2	Excitation
989.790	1	0	0	0	0	1	Excitation
991.514	2	0	0	0	0	2	Excitation
N_{III} #3							
685.816	23	22	4	18	0	1	Dissoc.
685.513	24	23	4	19	0	1	Dissoc.
686.335	25	23	4	19	0	2	Dissoc.
684.996	23	21	3	18	0	2	Dissoc.
O_{III} #1							
835.292	20	0	0	0	0	20	Excitation
833.742	6	0	0	0	0	6	Dissoc.
832.927	7	0	0	0	0	7	Dissoc.
835.096	41	0	0	0	0	41	Excitation
N_{IV} #1							
765.140	67	51	51	0	0	16	Dissoc.
N_V #1							
1238.81	<0.1	0	0	0	0	<0.1	Excitation
1242.80	<0.1	0	0	0	0	<0.1	Excitation

Table B.3.a-5. Molecular nitrogen, N_2: photon cross-sections for strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 6b)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products σ_{i_X}	σ_{i_A}	σ_{i_B}	Neutral σ_N	Neutral Product
N_{II} #2							
916.700	14-32	0	0	0	0	14-32	Excitation
916.004	.4-2.8	0	0	0	0	.4-2.8	Dissoc.
915.955	.4-2.8	0	0	0	0	.4-2.8	Dissoc.
915.603	.8-1.7	0	0	0	0	.8-1.7	Excitation
N_{III} #2							
764.357	13	10	10	0	0	3	Dissoc.
763.340	28	19	19	0	0	9	Dissoc.
O_{III} #2							
703.850	22	20	4	16	0	2	Dissoc.
702.899	23	21	4	17	0	2	Dissoc.
702.822	23	21	4	17	0	2	Dissoc.
702.332	24	22	5	17	0	2	Dissoc.
O_{IV} #1							
790.203	22	10	10	0	0	12	Dissoc.
787.710	10	8	8	0	0	2	Dissoc.
790.103	28	11	11	0	0	17	Dissoc.
O_V #1							
629.732	23	23	8	9	6	0	-

Table B.3.a-6. Molecular oxygen, O_2: photon cross-sections for very strong emission lines in megabarns ($10^{-18}cm^2$). (Source: R-12, Table 7a)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products			Neutral σ_N	Neutral Product
			σ_{ix}	σ_{iaA}	σ_{ib}		
N_{II} #1							
1085.70	2.4	0	0	0	0	2.4	Dissoc.
1084.57	1.4	0	0	0	0	1.4	Dissoc.
1083.98	1.1	0	0	0	0	1.1	Dissoc.
1085.54	2.2	0	0	0	0	2.2	Dissoc.
O_{II} #1							
834.467	11	4	4	0	0	7	Dissoc.
833.332	15	6	6	0	0	9	Dissoc.
832.762	26	10	10	0	0	16	Dissoc.
N_{III} #1							
991.579	1.8	1.2	1.2	0	0	0.6	Dissoc.
989.790	1.4	1.0	1.0	0	0	0.4	Dissoc.
991.514	1.8	1.2	1.2	0	0	0.6	Dissoc.
N_{III} #3							
685.816	18	18	6	10	2	0	-
685.513	18	18	6	10	2	0	-
686.335	22	22	7	13	2	0	-
684.996	26	26	9	15	2	0	-
O_{III} #1							
835.292	10	4	4	0	0	6	Dissoc.
833.742	13	5	5	0	0	8	Dissoc.
832.927	26	10	10	0	0	16	Dissoc.
835.096	10	4	4	0	0	6	Dissoc.
N_{IV} #1							
765.140	23	12	11	1	0	11	Dissoc.
N_V #1							
1238.81	0.3	0	0	0	0	0.3	Dissoc.
1242.80	4±2	0	0	0	0	4±2	Dissoc.

Table B.3.a-7. Molecular oxygen, O_2: photon cross-sections for strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 7b)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products σ_{ix}	σ_{iaA}	σ_{ib}	Neutral σ_N	Neutral Product
N_{II} #2							
916.700	16	10	10	0	0	6	Dissoc.
916.004	5	3	3	0	0	2	Dissoc.
915.955	5	3	3	0	0	2	Dissoc.
915.603	5	3	3	0	0	2	
N_{III} #2							
764.357	18	10	9	1	0	8	Dissoc.
763.340	22	12	11	1	0	10	Dissoc.
O_{III} #2							
703.850	28	25	13	12	0	3	Dissoc.
702.899	30	26	14	12	0	4	Dissoc.
702.822	30	26	14	12	0	4	Dissoc.
702.332	21	18	10	8	0	3	Dissoc.
O_{IV} #1							
790.203	28	10	10	0	0	18	Dissoc.
787.710	24	13	13	0	0	11	Dissoc.
790.103	28	10	10	0	0	18	Dissoc.
O_V #1							
629.732	30	29	6	10	12	1	Dissoc.

Table B.3.a-8. Atomic oxygen O, and atomic nitrogen, N: photon cross-sections for very strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 8a)

Emission Lines (A)	ATOMIC OXYGEN				ATOMIC NITROGEN
	Total	Ion Products			Total
	σ_i	σ_{iS}	σ_{iD}	σ_{iP}	σ_i
N_{II} #1					
1085.70	0	0	0	0	0
1084.57	0	0	0	0	0
1083.98	0	0	0	0	0
1085.54	0	0	0	0	0
O_{II} #1					
834.467	2.6	2.6	0	0	10
833.332	2.6	2.6	0	0	10
832.762	2.6	2.6	0	0	10
N_{III} #1					
991.579	0	0	0	0	0
989.790	0	0	0	0	0
991.514	0	0	0	0	0
N_{III} #3					
685.816	6.5	3.0	3.5	0	6
685.513	6.5	3.0	3.5	0	6
686.335	6.5	3.0	3.5	0	6
684.996	6.5	3.0	3.5	0	6
O_{III} #1					
835.292	2.6	2.6	0	0	10
833.742	2.6	2.6	0	0	10
832.927	2.6	2.6	0	0	10
835.096	2.6	2.6	0	0	10
N_{IV} #1					
765.140	3.0	3.0	0	0	10
N_V #1					
1238.81	0	0	0	0	0
1242.80	0	0	0	0	0

Table B.3.a-9. Atomic oxygen, O, and atomic nitrogen, N: photon cross-sections for strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 8b)

Emission Lines (A)	ATOMIC OXYGEN				ATOMIC NITROGEN
	Total σ_i	Ion Products			Total σ_i
		σ_{iS}	σ_{iD}	σ_{iP}	
N_{II} #2					
916.700	0	0	0	0	0
916.004	0	0	0	0	0
915.955	0	0	0	0	0
915.603	0	0	0	0	0
N_{III} #2					
764.357	3.0	3.0	0	0	10
763.340	3.0	3.0	0	0	10
O_{III} #2					
703.850	6.5	3.0	3.5	0	9
702.899	6.5	3.0	3.5	0	9
702.822	6.5	3.0	3.5	0	9
702.332	6.5	3.0	3.5	0	9
O_{IV} #1					
790.203	2.9	2.9	0	0	10
787.710	2.9	2.9	0	0	10
790.103	2.9	2.9	0	0	10
O_V #1					
629.732	9.0	2.7	4.0	2.3	12

Table B.3.a-10. Nitric oxide, NO: photon cross-sections for very strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 9a)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products			Neutral σ_N
			σ_{iX}	σ_{iA}	σ_{iB}	
N_{III} #1						
1085.70	9	7	7	0	0	2
1084.57	8	6	6	0	0	2
1083.98	8	6	6	0	0	2
1085.54	9	7	7	0	0	2
O_{II} #1						
834.467	21	11	11	0	0	10
833.332	20	10	10	0	0	10
832.762	16	9	9	0	0	7
N_{III} #1						
991.579	17	8	8	0	0	9
989.790	18	9	9	0	0	9
991.514	17	8	8	0	0	9
N_{III} #3						
685.816	18	17	5	7	5	1
685.513	18	17	5	7	5	1
686.335	21	19	6	7	6	2
684.996	19	17	5	7	5	2
O_{III} #1						
835.292	21	9	9	0	0	12
833.742	18	9	9	0	0	9
832.927	17	10	10	0	0	7
835.096	22	10	10	0	0	12
N_{IV} #1						
765.140	15	9	6	3	0	6
N_{V} #1						
1238.81	2.1	1.6	1.6	0	0	0.5
1242.80	2.1	1.7	1.7	0	0	0.4

Table B.3.a-11. Nitric oxide, NO: photon cross-sections for strong emission lines in megabarns (10^{-18} cm^2). (Source: R-12, Table 9b)

Emission Lines (A)	Total σ_T	Ionization σ_i	Ion Products σ_{iX}	σ_{iA}	σ_{iB}	Neutral σ_N
N_{II} #2						
916.700	31	9	9	0	0	22
916.004	30	10	10	0	0	20
915.955	30	10	10	0	0	20
915.603	29	10	10	0	0	19
N_{III} #2						
764.357	34	19	13	6	0	15
763.340	13	6	4	2	0	7
O_{III} #2						
703.850	21	18	7	8	3	3
702.899	20	18	7	8	3	2
702.822	20	18	7	8	3	2
702.332	19	18	7	8	3	1
O_{IV} #1						
790.203	18	10	9	1	0	8
787.710	17	11	10	1	0	6
790.103	17	10	9	1	0	7
O_V #1						
629.732	21	21	5	8	8	0

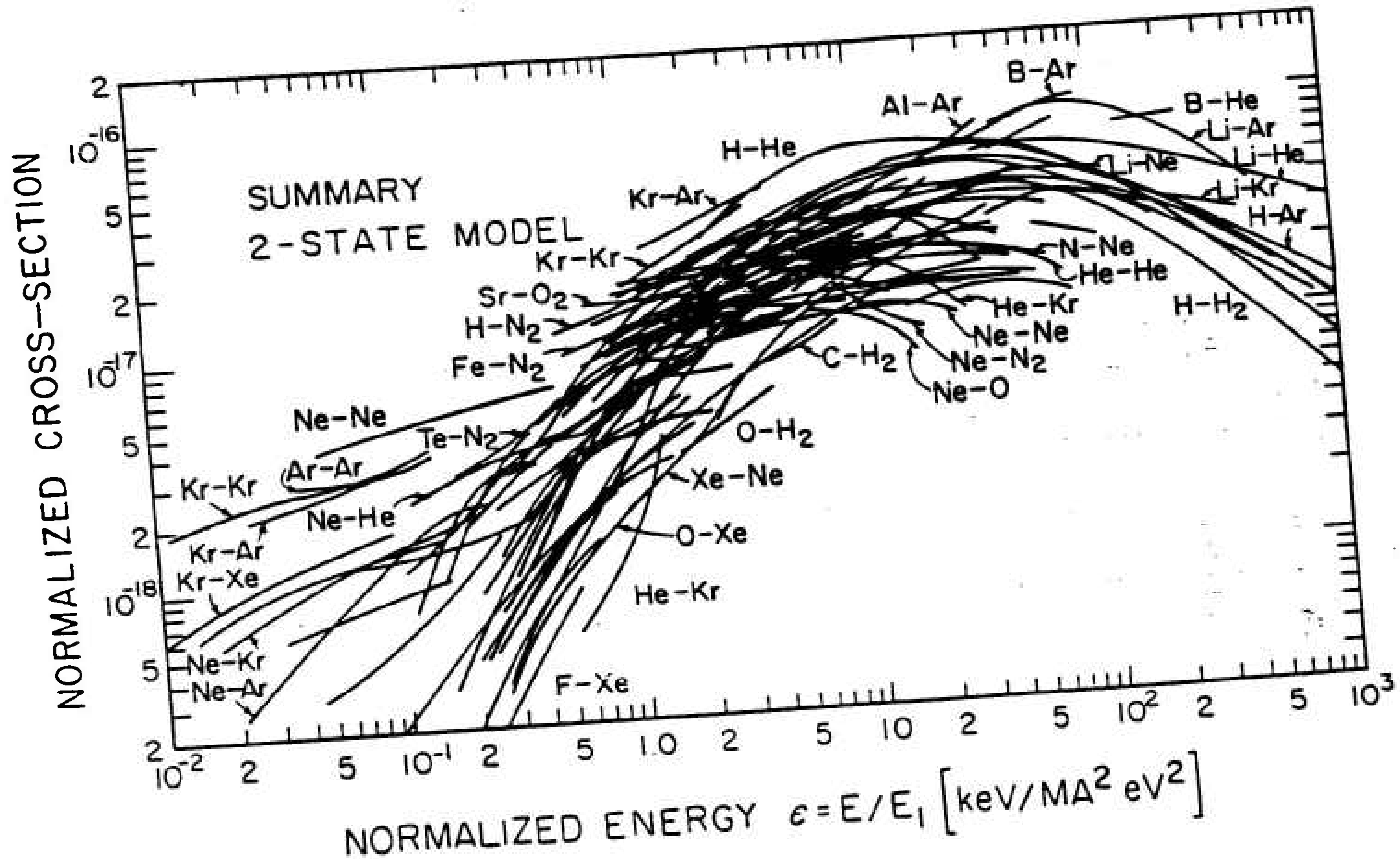

Figure B.3.a-67. Result of published heavy particle collision data scaled to give a normalized universal curve. (Source: R-15, Figure 1)

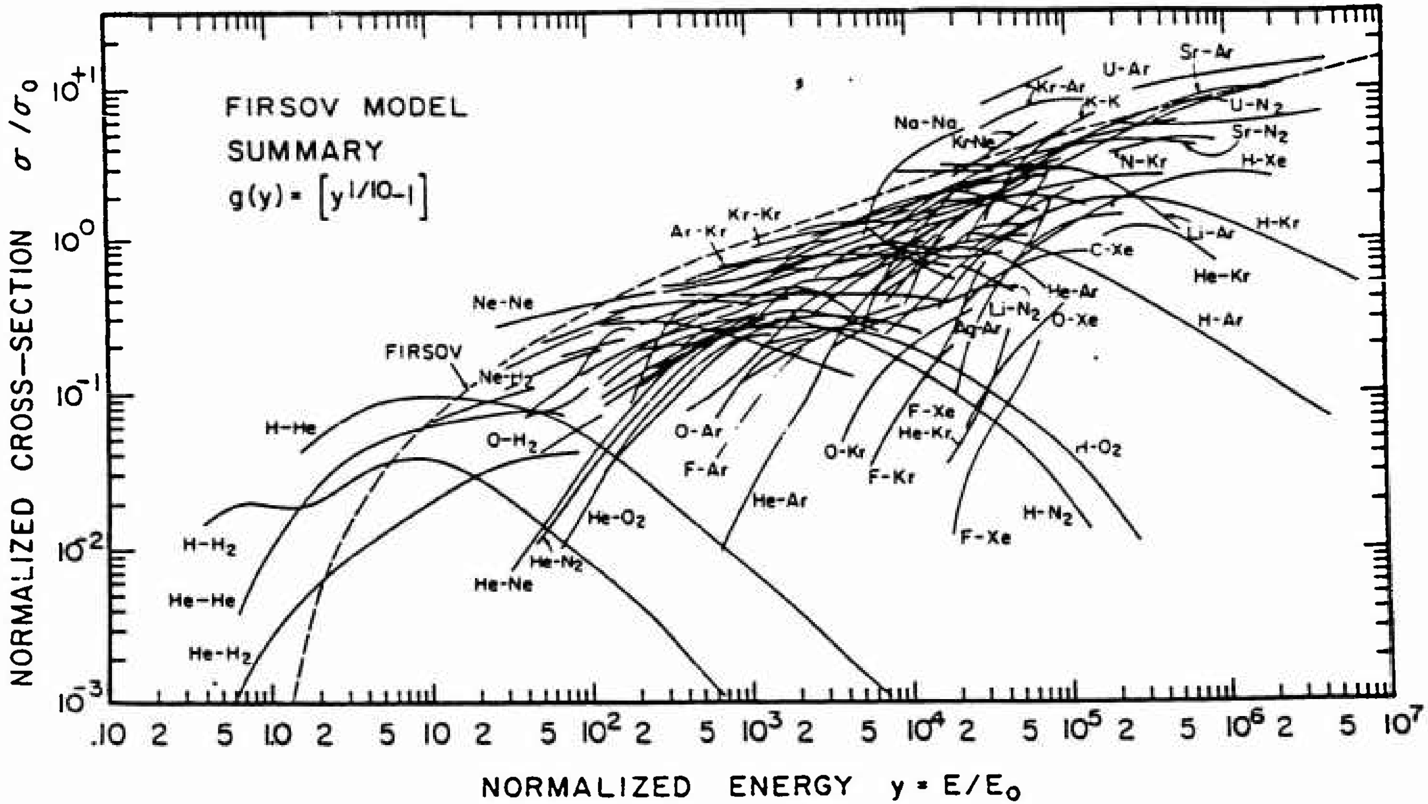

Figure B.3.a-68. Experimental heavy particle collision data scaled and compared with statistical theory. (Source: R-15, Figure 2)

NOTES

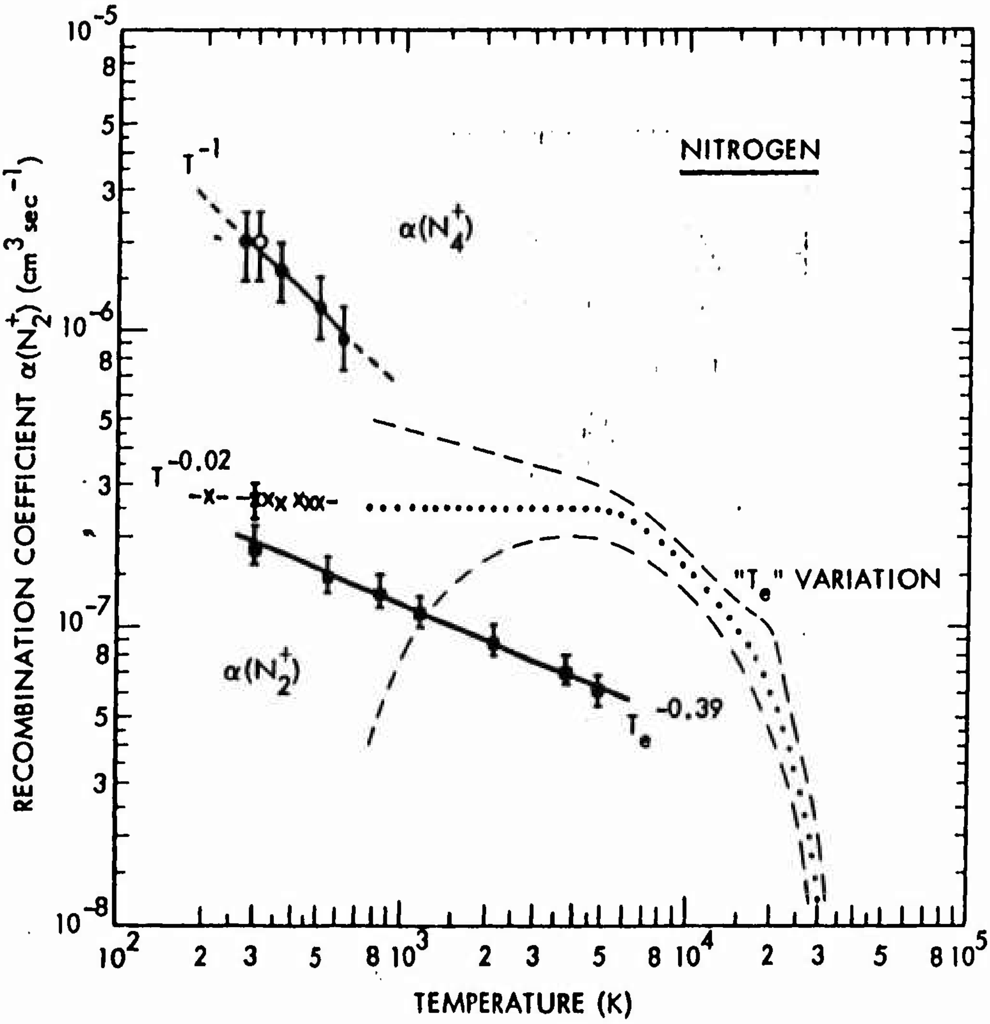

Figure B.3.b-1. Two-body electron-ion recombination coefficients, $\alpha(N_2^+)$ and $\alpha(N_4^+)$. The symbol T refers to conditions such that $T_e = T_+ = T_{gas}$ and the symbol T_e to the condition $T_+ = T_{gas} = 300$ K, with T_e variable. (Source: R-16, Figure 1)

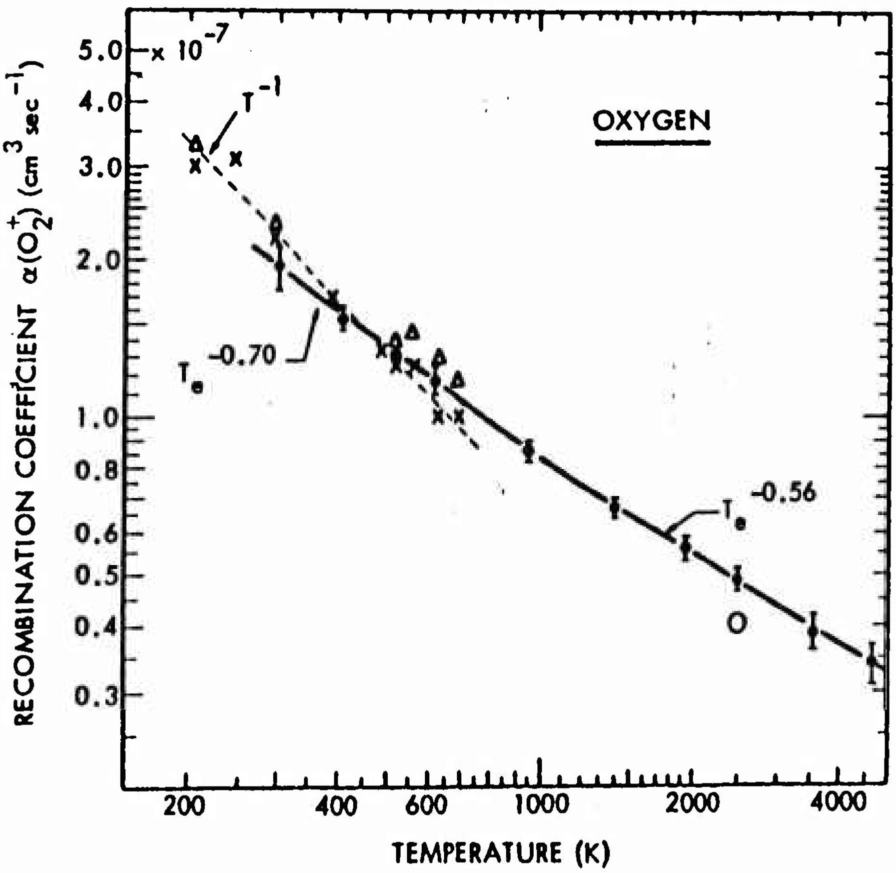

Figure B.3.b-2. Two-body electron-ion recombination coefficient $\alpha(O_2^+)$ as a function of temperature. (Souroe: R-16, Figure 3)

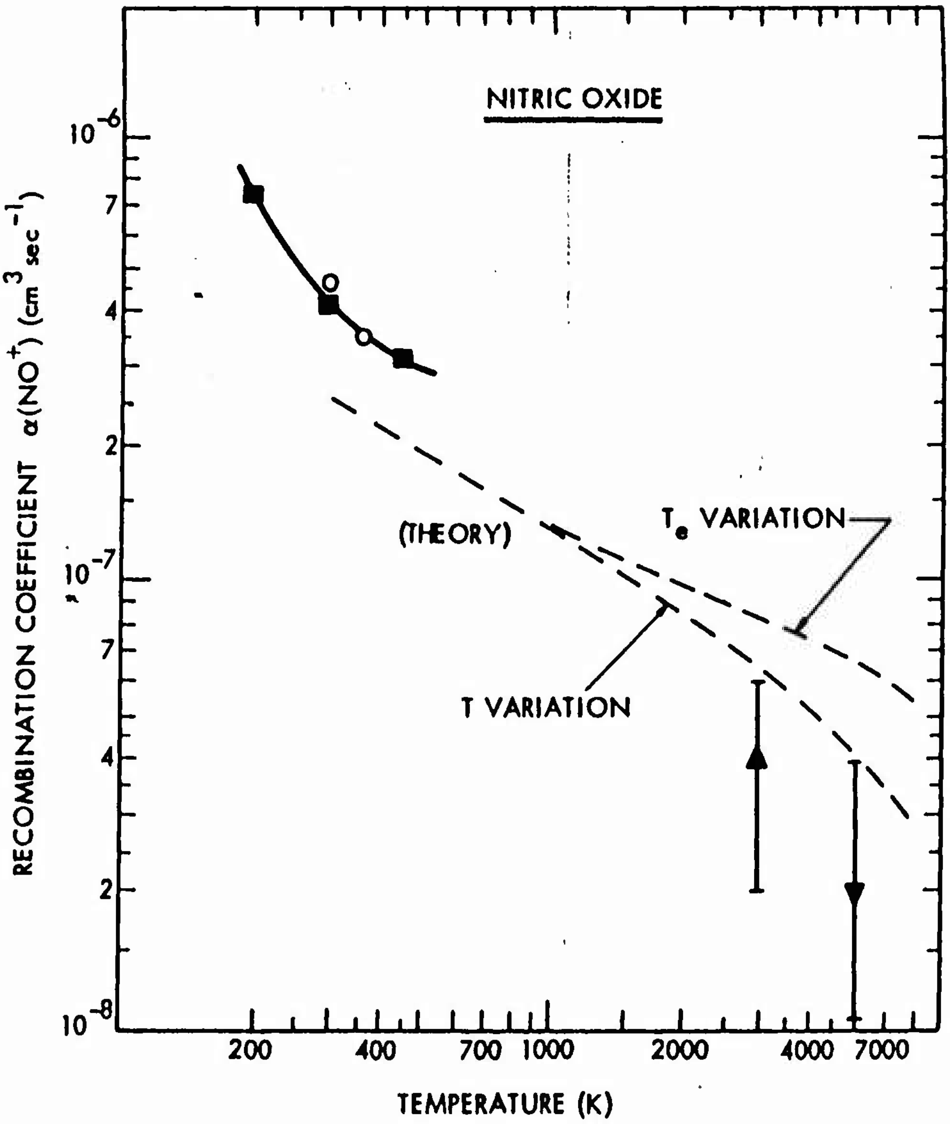

Figure B.3.b-3. Two-body electron-ion recombination coefficient $\alpha(NO^+)$ as a function of temperature. Experimental results for $T_e = T_+ = T_{gas}$. Theoretical calculations are also shown. (Source: R-16, Figure 2)

Table B.3.b-1. Radiative recombination reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (I))

No.	Reaction	a	b	c	Notes
1.	$O^+ + e \rightarrow O + h\nu$	(3.5±1.0) [-12]	(-0.7±0.1)	0	
2.	$N^+ + e \rightarrow N + h\nu$	(3.5±1.0) [-12]	(-0.7±0.1)	0	
3.	$H^+ + e \rightarrow H + h\nu$	(3.5±1.0) [-12]	(-0.7±0.1)	0	
4.	$O_2^+ + e \rightarrow O_2 + h\nu$	(4) [-12±1]	(-0.7±0.5)	0	Very small compared to dissociative recombination; estd. values
5.	$N_2^+ + e \rightarrow N_2 + h\nu$	(4) [-12±1]	(-0.7±0.5)	0	
6.	$NO^+ + e \rightarrow NO + h\nu$	(4) [-12±1]	(-0.7±0.5)	0	

Table B.3.b-2. Three-body recombination reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (III))

No.	Reaction	a	b	c	Notes
1. a.	$X^{+} + e + M \rightarrow$ Products	(2) [-27.0±0.2]	(-2.5)	0	X^{+} = atomic ion: M = atom
		(6) [-27.0±0.3]	(-2.5)	0	M = molecule
		(3) [-26.0±0.3]	(-2.5)	0	M = polar molecule
		(Partially estd. values)			
b.	$XY^{+} + e + M \rightarrow$ Products	(6) [-27.0±0.3]	(-2.5)	0	XY^{+} = molecular ion: M = atom or molecule
		(3) [-26.0±0.3]	(-2.5)	0	M = polar molecule
		(Partially estd. values)			
c.	X^{+}(cluster) + e + M → Products	(5) [-26.0±0.3]	(-2.5)	0	X^{+}(cluster) = any clustered ion. M = any third body; estd. values
2. a.	$X^{+} + e + e \rightarrow$ Products	(7±3) [-20]	(-4.5)	0	X^{+} = any atomic or molecular ion.
b.	X^{+}(cluster) + e + e → Products	(3) [-19.0±0.3]	(-4.5)	0	X^{+}(cluster) = any clustered ion; estd. values

Table B.3.b-3. Dissociative recombination reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1(IV))

No.	Reaction	a	b	c	Notes
1. a.	$O_2^+ + e \rightarrow O + O$	$(2.1 \pm 0.2)\,[-7]$	(-0.63 ± 0.07)	0	$T = T_e$; partially estd. values
		For $T_{iv} > \sim 1000$ K, multiply above formula by a factor $\left[1 - \exp\left(-2677/T_{iv}\right)\right]$.			
b.	$\rightarrow 1.0\,O(^3P) + 0.9\,O(^1D) + 0.1\,O(^1S)$	$(2.1 \pm 0.2)\,[-7]$	(-0.63 ± 0.07)	0	$T = T_e$; partially estd. values
		Branching measured at 300 K; branching ratio probably changes with increasing T.			
2. a.	$N_2^+ + e \rightarrow N + N$	$\left(1.8^{+0.4}_{-0.2}\right)[-7]$	(-0.39)	0	$T = T_e$; partially estd. values
		For $T_{iv} > \sim 1200$ K, multiply above formula by a factor $\left[1 - \exp\left(-3162/T_{iv}\right)\right]$.			
b.	$\rightarrow 1.08\,N(^2D) + 0.92\,N(^4S)$	Theoretical branching ratio.			Estd. value
3. a.	$NO^+ + e \rightarrow N + O$	$(4.0 \pm 0.3)\,[-7]$	(-1.0 ± 0.2)	0	T = 200–300 K
b.	$\rightarrow N + O$	$(4.0 \pm 0.3)\,[-7]$	(-0.8 ± 0.2)	0	$T = T_e$; partially estd. values
		For $T_{iv} > \sim 1300$ K, multiply above formula by a factor $\left[1 - \exp\left(-3230/T_{iv}\right)\right]$.			
c.	$\rightarrow N(^2D) + O(^3P)$	Theoretical prediction.			Estd. value
4.	$N_3^+ + e \rightarrow N + N_2$	$(7 \pm 4)\,[-7]$	(-1.0 ± 0.5)	0	Estd. values
5.	$N_4^+ + e \rightarrow N_2 + N_2$	$(2 \pm 1)\,[-6]$	(-1.0 ± 0.3)	0	
6.	$NO_2^+ + e \rightarrow$ Products	$(3 \pm 2)\,[-7]$	(-0.5 ± 0.2)	0	$T = T_e$; estd. values
7.	$NO^+ \cdot NO + e \rightarrow NO + NO$	$(1.7 \pm 0.5)\,[-6]$	(-1.0 ± 0.5)	0	Partially estd. values

Table B.3.b-3. (Continued)

No.	Reaction	a	b	c	Notes
8.	$NO^+ \cdot H_2O + e \rightarrow N + O + H_2O$	(1) [-6]	$\left(-0.2^{+0.2}_{-0.8}\right)$	0	Estd. values
9.	$NO^+(H_2O)_2 + e \rightarrow N + O + 2H_2O$	(2) [-6]	$\left(-0.2^{+0.2}_{-0.8}\right)$	0	Estd. values
10.	$NO^+(H_2O)_3 + e \rightarrow N + O + 3H_2O$	(3) [-6]	$\left(-0.2^{+0.2}_{-0.8}\right)$	0	Estd. values
11.	$O_2^+ \cdot O_2 + e \rightarrow O + O + O_2$	(2.0±0.5) [-6]	(-1.0±0.5)	0	
12.	$O_2^+ \cdot H_2O + e \rightarrow O + O + H_2O$	(1.5) [-6]	$\left(-0.2^{+0.2}_{-0.8}\right)$	0	Estd. values
13.	$H_3O^+ + e \rightarrow H_2O + H$; $\rightarrow H_2 + OH$	(1.3±0.3) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	Products Uncertain (rows 8–19)
14.	$H_3O^+ \cdot H_2O + e \rightarrow 2H_2O + H$; $\rightarrow H_2 + OH + H_2O$	(2.8±0.4) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	
15.	$H_3O^+(H_2O)_2 + e \rightarrow 3H_2O + H$; $\rightarrow H_2 + OH + 2H_2O$	(5.1±0.7) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	
16.	$H_3O^+(H_2O)_3 + e \rightarrow 4H_2O + H$; $\rightarrow H_2 + OH + 3H_2O$	(6.1±1.2) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	
17.	$H_3O^+(H_2O)_4 + e \rightarrow 5H_2O + H$; $\rightarrow H_2 + OH + 4H_2O$	(7.4±1.5) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	
18.*	$H_3O^+(H_2O)_5 + e \rightarrow 6H_2O + H$; $\rightarrow H_2 + OH + 5H_2O$	(9.3±2.0) [-6]	$\left(-0.2^{+0.1}_{-0.4}\right)$	0	
19.	$H_3O^+ \cdot OH + e \rightarrow H_2O + H + OH$; $\rightarrow H_2 + OH + OH$	(3) [-6]	(-1.0±0.5)	0	

*For the analogous reactions for higher hydrates, i.e., $H_3O^+(H_2O)_n$, where n≥6, use the rate coefficients for Reaction 18.

Table B.3.b-4. Mutual neutralization reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (V))

No.	Reaction	a	b	c	Notes
1.	$O^+ + O^- \rightarrow O + O$	(2.7±1.3)[-7]	(-0.5)	0	
2.	$O_2^+ + O^- \rightarrow$ Products (Probably $O_2 + O$)	(9.6±3.0)[-8]	(-0.5)	0	
3.	$O_2^+ + O_2^- \rightarrow$ Products (Probably $O_2 + O_2$)	(4.2±1.3)[-7]	(-0.5)	0	
4.	$O_2^+ + NO_2^- \rightarrow$ Products (Probably $O_2 + NO_2$)	(4.1±1.3)[-7]	(-0.5)	0	
5.	$O_2^+ + NO_3^- \rightarrow$ Products (Probably $O_2 + NO_3$)	(1.3±0.5)[-7]	(-0.5)	0	
6.	$N_2^+ + O_2^- \rightarrow$ Products (Probably $N_2 + O_2$)	(1.6±0.5)[-7]	(-0.5)	0	
7.	$NO^+ + O^- \rightarrow$ Products (Probably $NO + O$)	(4.9±1.5)[-7]	(-0.5)	0	
8.	$NO^+ + NO_2^- \rightarrow$ Products (Probably $NO + NO_2$)	(3.5±2.0)[-7]	(-0.5)	0	
9.	$NO^+ + NO_3^- \rightarrow$ Products (Probably $NO + NO_3$)	$\left(4^{+5}_{-3}\right)$[-7]	(-0.5)	0	
10.	$N^+ + O^- \rightarrow N + O$	(2.6±0.8)[-7]	(-0.5)	0	

Table B.3.b-4. (Continued)

No.	Reaction	a	b	c	Notes
11.	$N^+ + Y^- \rightarrow$ Products (Probably X + Y)	$\left(1.0^{+4.0}_{-0.9}\right)[-7]$	(−0.5)	0	X^+ and Y^- are either atomic or molecular; estd. values
12.	X^+(cluster) + $Y^- \rightarrow$ Products	(5)[−7.0±0.3]	(−0.5)	0	X^+(cluster) and Y^-(cluster) are any clustered ions; estd. values
13.	X^+ + Y^-(cluster) $\rightarrow$ Products	(5)[−7.0±0.3]	(−0.5)	0	
14.	X^+(cluster) + Y^-(cluster) $\rightarrow$ Products	(5)[−7.0±0.3]	(−0.5)	0	

Table B.3.b-5. Three-body ion-ion recombination reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (VI))

No.	Reaction	a	b	c	Notes
1.	$X^+ + Y^- + M \rightarrow$ Products	(3±1)[−25]	(−2.5)	0	X^+, Y^-, and M are either atomic or molecular "air" species.
2.	X^+(cluster) + $Y^- + M \rightarrow$ Products	(3±1)[−25]	(−2.5)	0	X^+(cluster) and Y^-(cluster) are any clustered ions; estd. values
3.	X^+ + Y^-(cluster) + $M \rightarrow$ Products	(3±1)[−25]	(−2.5)	0	
4.	X^+(cluster) + Y^-(cluster) + $M \rightarrow$ Products	(3±1)[−25]	(−2.5)	0	

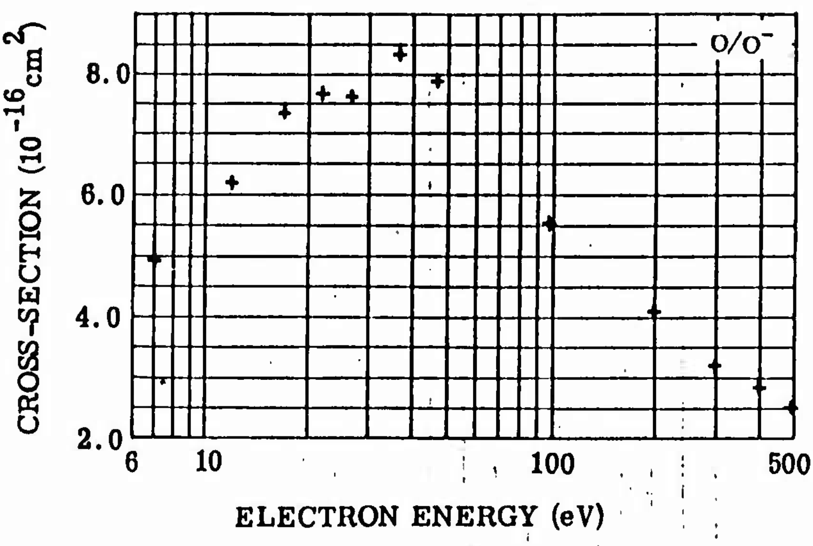

Figure B.3.c-1. (Source: R-14, Figure 2)

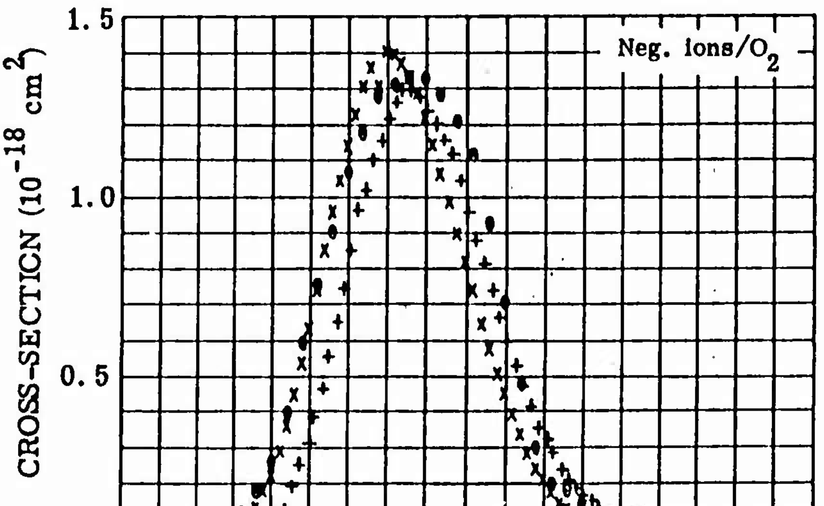

Figure B.3.c-2. (Source: R-14, Figure 60)

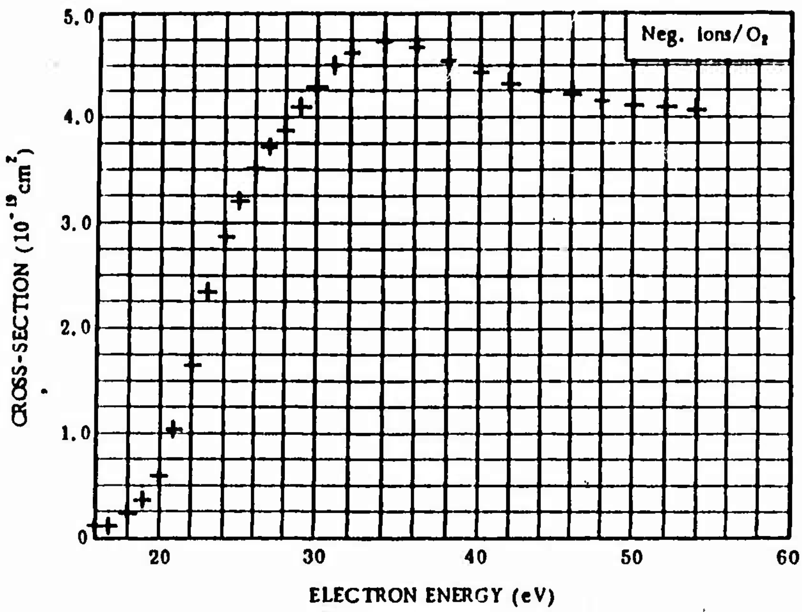

Figure B.3.c-3. (Source: R-14, Figure 61)

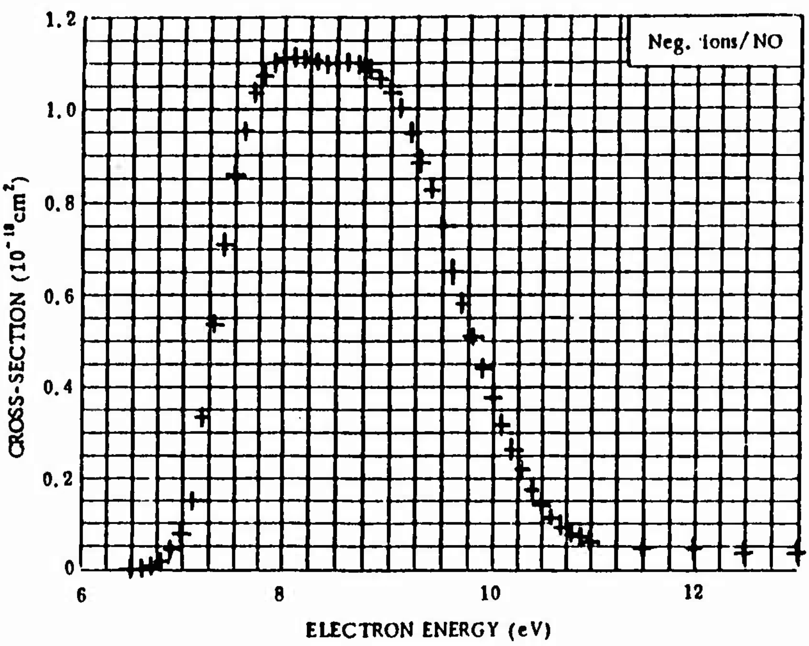

Figure B.3.c-4. (Source: R-14, Figure 44)

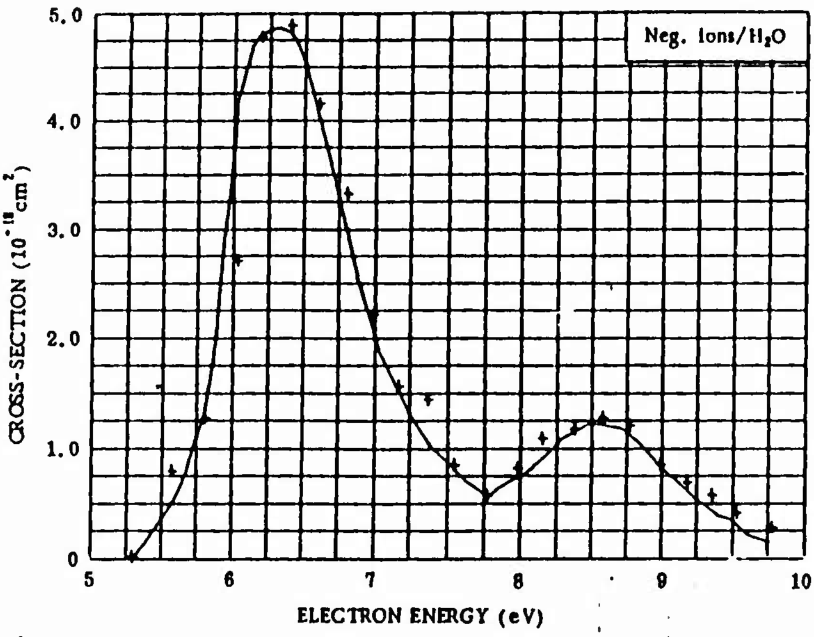

Figure B.3.c-5. (Source: R-14, Figure 65)

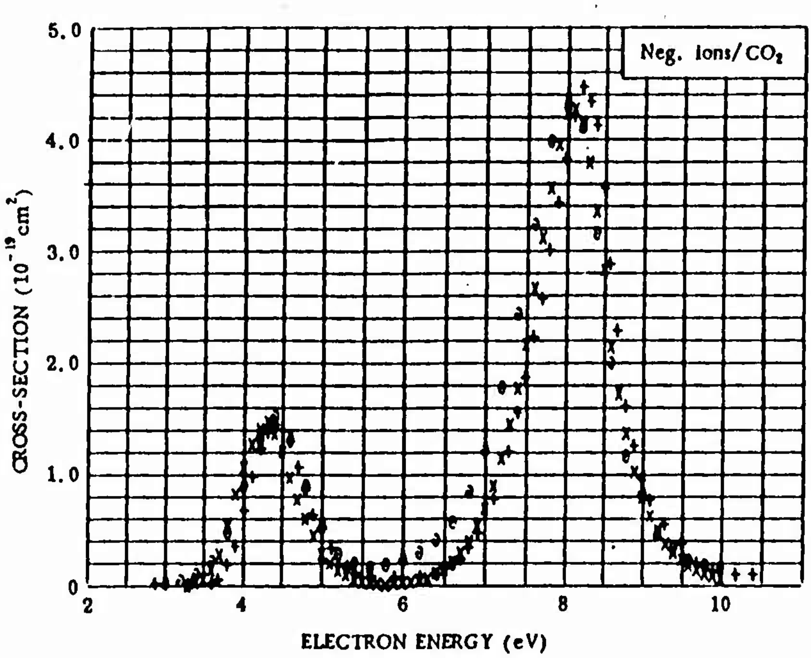

Figure B.3.c-6. (Source: R-14, Figure 80)

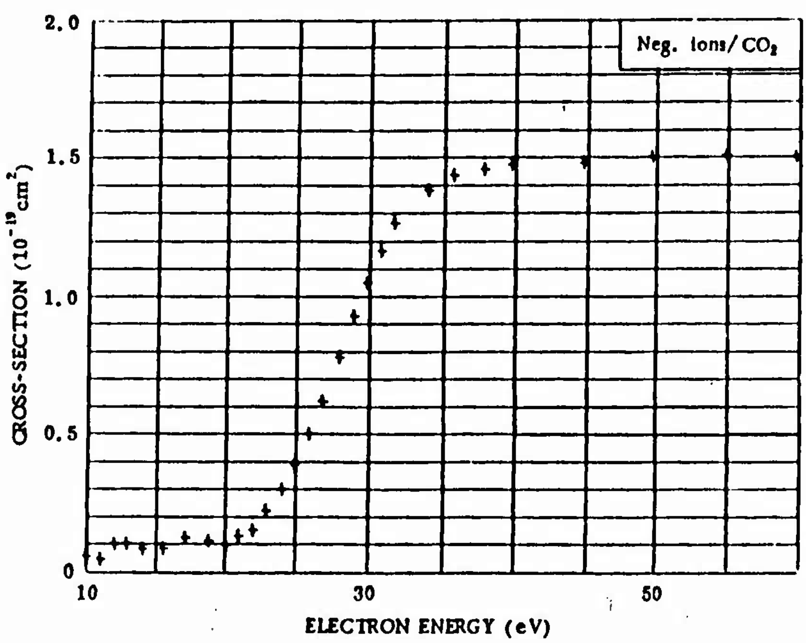

Figure B.3.c-7. (Source: R-14, Figure 81)

Table B.3.c-1. Radiative attachment reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (VII))

No.	Reaction	a	b	c	Notes
1.	$O + e \rightarrow O^- + h\nu$	(1.3±0.1)[-15]	0	0	
2.	$O_2 + e \rightarrow O_2^- + h\nu$	(2)[-19±1]	0	0	
3.	$O_3 + e \rightarrow O_3^- + h\nu$	(1)[-17±3]	0	0	Slow compared with Reactions 2(a, b) of Table B.3.c-5; estd. values
4.	$NO_2 + e \rightarrow NO_2^- + h\nu$	(1)[-17±2]	0	0	See Reaction 7 of Table B.3.c-3; estd. values
5.	$OH + e \rightarrow OH^- + h\nu$	(2.5±1.5)[-15]	(-0.25)	0	Detailed balance calculation

Table B.3.c-2. Photodetachment reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (VIII))

No.	Reaction	a	b	c	Notes
1.	$O^- + h\nu \rightarrow O + e$	$(1.4 \pm 0.1)[0]$	0	0	These values are for normal-incidence, unattenuated solar flux at top of earth's atmosphere.
2.	$O_2^- + h\nu \rightarrow O_2 + e$	$(0.33 \pm 0.10)\ [0]$	0	0	
3.	$O_3^- + h\nu \rightarrow O_3 + e$	$(2 \pm 1)[-1]$	0	0	Vary with altitudes and solar zenith angles.
4.	$O_2^- \cdot O_2 + h\nu \rightarrow O_2 + O_2 + e$	$(2)\ [0.0 \pm 0.3]$	0	0	See Reaction 1 of Table B.3.d-9.
5.	$NO_2^- + h\nu \rightarrow NO_2 + e$	$(8)[-2 \pm 2]$	0	0	
6.	$NO_3^- + h\nu \rightarrow NO_3 + e$	$(5)[-3 \pm 2]$	0	0	
7.	$OH^- + h\nu \rightarrow OH + e$	$(1)[0 \pm 1]$	0	0	
8.	$CO_4^- + h\nu \rightarrow CO_2 + O_2 + e$	$(3)[-1 \pm 2]$	0	0	

Table B.3.c-3. Three-body attachment reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (IX))

No.	Reaction	a	b	c	Notes
1.	$O_2 + e + O \rightarrow O_2^- + O$	(1) [-31±2]	0	0	No experimental data; estd. values.
2.	$O_2 + e + O_2 \rightarrow O_2^- + O_2$	(1.4±0.2) [-29]	(-1)	600	T = 195-600 K k_{300} = (1.9±0.3) [-30]
3.	$O_2 + e + N_2 \rightarrow O_2^- + N_2$	(1.0±0.5) [-31]	0	0	
4.	$O_2 + e + H_2O \rightarrow O_2^- + H_2O$	(1.4±0.2) [-29]	0	0	T = 300-400 K
5.	$O_2 + e + CO_2 \rightarrow O_2^- + CO_2$	(3.3±0.7) [-30]	0	0	T = 300-525 K
6.	$NO + e + M \rightarrow$ Products	(8) [-31]	0	0	M = NO
7.	$NO_2 + e (+M) \rightarrow NO_2^- (+M)$	(4) [-11]	0	0	Observed to be a saturated 3-body process. k is the effective 2-body value. See Reaction 4 of Table B.3.c-1.

Table B.3.c–4. Collisional detachment reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1, (X))

No.	Reaction	a	b	c	Notes
1.	$O^- + O_2 \rightarrow O + e + O_2$	(2.3±1.0) [-9]	0	26,000 ±3000	$T_i < 20,000$ K; k_{300} = (1.0) [-46]
2.	$O^- + N_2 \rightarrow O + e + N_2$	(2.3) [-9.0±0.5]	0	26,000 ±3000	$T_i < 20,000$ K; k_{300} = (1.0) [-46]
3.	$O_2^- + O \rightarrow O_2 + e + O$	(3.6) [-11]	0	5000	Detailed balance calculation. k_{300} = (2.1) [-18]
4.	$O_2^- + N_2 \rightarrow O_2 + e + N_2$	(1.9±0.4) [-12]	(1.5)	4990	T = 375–600 K; k_{300} = (1.1±0.2) [-19]
5.	$O_2^- + O_2 \rightarrow O_2 + e + O_2$	(2.7±0.3) [-10]	(0.5)	5590	T = 375–600 K; k_{300} = (2.2±0.2) [-18]
6.	$O_2^- + O_2(a\,^1\Delta_g) \rightarrow O_2 + e + O_2$	$\left(2^{+2}_{-1}\right)$ [-10]	0	0	
7.	$O_2^- + H_2O \rightarrow O_2 + e + H_2O$	(5.0) [-9]	0	5000	Detailed balance calculation. k_{300} = (2.9) [-27]
8.	$O_2^- + CO_2 \rightarrow O_2 + e + CO_2$	(1.2) [-9]	0	5000	Detailed balance calculation. k_{300} = (7.0) [-28]

Table B.3.c-5. Dissociative attachment reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XI))

No.	Reaction	a	b	c	Notes
1.	$O_2 + e \rightarrow O^- + O$	-	-	-	k<(1)[-16] for T < 2000 K Endothermic c> (4)[4] at T<300 K. Strong dependence on T_v at high T_e.
2. a.	$O_3 + e \rightarrow O^- + O_2$	(9±2)[-12]	(1.5)	0	T = 200–300 K See Reaction 3 of Table B.3.c-1.
b.	$\rightarrow O_2^- + O$	(1.7)[-11.0±0.3]	(1.5)	13200	$T = T_e$; estd. values No dependence on T for T < 360 K. k_{300} = (1.3) [-30]

Table B.3.c-6. Associative detachment reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XII))

No.	Reaction	a	b	c	Notes
1.	$O^- + O \rightarrow O_2 + e$	$\left(2^{+2}_{-1}\right)[-10]$	0	0	
2.	$O^- + O_2 \rightarrow O_3 + e$	-	-	-	$k < (5)[-15]$ at $T = 300$ K and $T_i = 300$-10000 K Endothermic $c \sim 5000$
3.	$O^- + O_2(a\,^1\Delta_g) \rightarrow O_3 + e$	$\left(3.0^{+3.0}_{-1.5}\right)[-10]$	0	0	Cf. Reaction 1 of Table B.3.d-3
4.	$O^- + O_3 \rightarrow O_2 + O_2 + e$	-	-	-	Rate is estd. slow, compared with Reaction 2 of Table B.3.d-3.
5.	$O^- + N \rightarrow NO + e$	$\left(2^{+2}_{-1}\right)[-10]$	0	0	
6.	$O^- + N_2 \rightarrow N_2O + e$	-	-	-	$k < (1)[-12]$ at $T_i = 300$ K
7.	$O^- + NO \rightarrow NO_2 + e$	$(2.2 \pm 0.5)[-10]$	(-0.56)	0	$T_i = 300$-2000 K
8.	$O^- + H_2 \rightarrow H_2O + e$	$(6.5 \pm 1.0)[-10]$	(-0.19)	0	$T = T_i < 3000$ K

Table B.3.c-6. (Continued)

No.	Reaction	a	b	c	Notes
9.	$O^- + CO \rightarrow CO_2 + e$	$(6 \pm 1)[-10]$	(−0.32)	0	$T = T_i < 3000$ K
10.	$O_2^- + O \rightarrow O_3 + e$	$\left(3.0^{+3.0}_{-1.5}\right)[-10]$	0	0	
11.	$O_2^- + N \rightarrow NO_2 + e$	$(5.0 \pm 2.5)[-10]$	0	0	
12.	$O_3^- + O \rightarrow O_2 + O_2 + e$	$(1)\left[-11^{+1}_{-2}\right]$	0	0	No experimental data; estd. values.
13.	$OH^- + O \rightarrow HO_2 + e$	$\left(2^{+2}_{-1}\right)[-10]$	0	0	
14.	$CO_3^- + O \rightarrow CO_2 + O_2 + e$	-	-	-	Rate is slow, compared with Reaction 22 of Table B.3.d-4.

NOTES

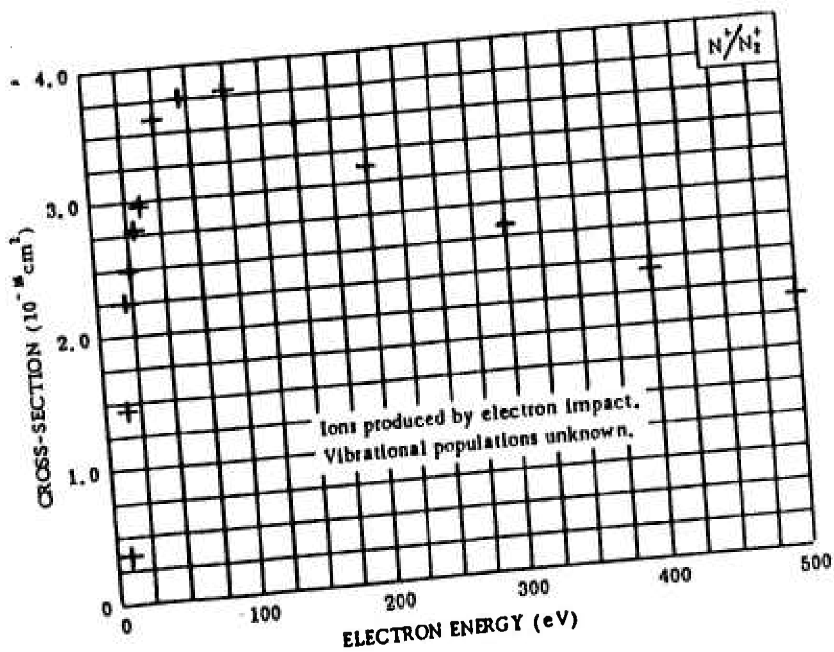

Figure B.3.d-1. (Source: R-14, Figure 90)

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Table B.3.d-1. Positive-ion charge transfer reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (XIII))

No.	Reaction	a	b	c	Notes
1.	$O^+ + H \rightarrow O + H^+$	(6.8±3.0)[-10]	0	0	
2.	$O^+ + O_2 \rightarrow O + O_2^+$	(2.0±0.2)[-11]	(-0.40±0.14)	0	T < 1800 K
		(1.3±0.2)[-12]	(1.20±0.13)	0	T > 1800 K
3.	$O^+(^2D) + O_2 \rightarrow O + O_2^+(a, A)$	$(3)\left[-10.0^{+0.5}_{-1.0}\right]$	0	0	
4.	$O^+ + NO \rightarrow O + NO^+$	-	-	-	Source R-18A gives k < (1.3)[-12]. See Reaction 2 of Table B.3.d-2.
5.	$O^+ + NO_2 \rightarrow O + NO_2^+$	(1.6±0.3)[-9]	0	0	Data at 393 K
6.	$O^+ + N_2O \rightarrow O + N_2O^+$	(2.2±1.0)[-10]	0	0	Cf. Reaction 3 of Table B.3.d-2.
7.	$O^+ + H_2O \rightarrow O + H_2O^+$	(2.3±0.3)[-9]	0	0	
8.	$O^+(^2D) + N_2 \rightarrow O + N_2^+$	(3)[-10±1]	0	0	
9.	$N^+ + O \rightarrow N + O^+$	(1)[-12]	0	0	Estd. values

Table B.3.d-1. (Continued)

No.	Reaction	a	b	c	Notes
10.*	$N^+ + O_2 \rightarrow N + O_2^+$	(2.8±1.0)[-10]	$\left(0.00^{+0.80}_{-0.17}\right)$	0	T < 4600 K
		(6±1)[-11]	(0.57±0.05)	0	T > 4600 K
11.	$N^+ + NO \rightarrow N + NO^+$	(8.0±2.4)[-10]	0	0	
12.	$N^+ + H_2O \rightarrow N + H_2O^+$	(2.6±0.4)[-9]	0	0	
13.	$N^+ + CO \rightarrow N + CO^+$	(9±3)[-10]	0	0	
14.	$N^+ + CO_2 \rightarrow N + CO_2^+$	(1.3±0.4)[-9]	0	0	
15.	$O_2^+ + NO \rightarrow O_2 + NO^+$	(6.3±2.4)[-10]	0	0	
16.	$O_2^+ + NO_2 \rightarrow O_2 + NO_2^+$	(6.6±2.0)[-10]	0	0	Cf. Reaction 10 of Table B.3.d-2.

*The sum of Reaction 10 of this table and Reaction 6 of Table B.3.d-2 represents one overall reaction, as measured experimentally, for which the division into the channels indicated is somewhat uncertain, and for which the energy dependence of the separate branches has not been measured. The rate constant for the overall process (both Reactions) is:

$$k = (5.5 \pm 0.5) \times 10^{-10} (T/300)^{\left(0.00^{+0.80}_{-0.17}\right)} \text{ at } T < 4600 \text{ K};$$

$$k = (1.2 \pm 0.2) \times 10^{-10} (T/300)^{(0.57 \pm 0.05)} \text{ at } T > 4600 \text{ K}.$$

These values have been arbitrarily halved between the two channels, as seemingly the most reasonable resolution of the problem at this time. The product N, in Reaction 10 of this table may include some proportion of the (^2D) state, but no experimental evidence is available to support any estimates in this regard.

Table B.3.d-1. (Continued)

No.	Reaction	a	b	c	Notes
17.	$O_2^+ + Na \rightarrow O_2 + Na^+$	(6.7) [-10±1]	0	0	Cf. Reaction 12 of Table B.3.d-2
18.	$O_2^+(a\ ^4\Pi_u) + N_2 \rightarrow O_2 + N_2^+$	(5±4) [-10]	0	0	
19.	$N_2^+ + O \rightarrow N_2 + O^+$	(6.6) [-11±1]	-	1945	Estd. values; no experimental data. Cf. Reaction 13 of Table B.3.d-2 k_{300} = (1) [-13±1].
20.	$N_2^+ + N \rightarrow N_2 + N^+$	-	-	-	k < (1) [-11]
21.	$N_2^+ + O_2 \rightarrow N_2 + O_2^+$	(5.0±1.0) [-10]	(-0.8±0.2)	0	T < 3560 K
		(2.5±0.5) [-13]	(1.4±0.3)	0	T > 3560 K; Cf. Reaction 14 of Table B.3.d-2.
22.	$N_2^+ + NO \rightarrow N_2 + NO^+$	(3.3±1.5) [-10]	0	0	$N_2(A)$ or $NO^+(a)$ may be formed.
23.	$N_2^+ + H_2O \rightarrow N_2 + H_2O^+$	-	-	-	This reaction combined with Reaction 16 of Table B.3.d-2 add to k= (2.2) [-9].

Table B. 3. d-1. (Continued)

No.	Reaction	a	b	c	Notes
24.	$N_2^+ + CO_2 \rightarrow N_2 + CO_2^+$	(9±3) [-10]	0	0	
25.	$N_2^+ + Na \rightarrow N_2 + Na^+$	(5. 8±3. 0) [-10]	0	0	
26.	$NO^+ + Na \rightarrow NO + Na^+$	(7. 0±3. 0) [-11]	0	0	
27.	$NO_2^+ + NO \rightarrow NO_2 + NO^+$	(2. 9±1. 0) [-10]	0	0	
28.	$H^+ + O \rightarrow H + O^+$	(3. 8±2. 0) [-10]	0	0	
29.	$H^+ + NO \rightarrow H + NO^+$	(1. 9±0. 5) [-9]	0	0	
30.	$OH^+ + O_2 \rightarrow OH + O_2^+$	(2. 0±0. 5) [-10]	0	0	
31.	$H_2O^+ + O_2 \rightarrow H_2O + O_2^+$	(2. 0±0. 5) [-10]	0	0	
32.	$CO^+ + O \rightarrow CO + O^+$	(1. 4±0. 8) [-10]	0	0	
33.	$CO^+ + NO \rightarrow CO + NO^+$	(3. 3±1. 0) [-10]	0	0	
34.	$CO_2^+ + O \rightarrow CO_2 + O^+$	(1. 0±0. 6) [-10]	0	0	Cf. Reaction 36 of Table B. 3. d-2.
35.	$CO_2^+ + O_2 \rightarrow CO_2 + O_2^+$	(5±2) [-11]	0	0	
36.	$CO_2^+ + NO \rightarrow CO_2 + NO^+$	(1. 2±0. 4) [-10]	0	0	

Table B.3.d-2. Positive ion-atom interchange reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XIV))

No.	Reaction	a	b	c	Notes
1.*	$O^+ + N_2 \rightarrow NO^+ + N$	(1.2±0.1)[-12]	(-1.0±0.4)	0	T < 750 K
		(8.0±2.0)[-14]	(2.0±0.2)	0	T > 750 K
2.	$O^+ + NO \rightarrow O_2^+ + N$	-	-	-	k = (1)[-12] See Reaction 4 of Table B.3.d-1.
3.	$O^+ + N_2O \rightarrow NO^+ + NO$	(2.3±1.0)[-10]	0	0	See Reaction 6 of Table B.3.d-1.
4.	$O^+ + H_2 \rightarrow OH^+ + H$	(2.0±0.5)[-9]	0	0	
5.	$O^+ + CO_2 \rightarrow O_2^+ + CO$	(1.1±0.3)[-9]	0	0	
6.**	$N^+ + O_2 \rightarrow NO^+ + O$	(2.8±1.0)[-10]	$\left(0.00^{+0.80}_{-0.17}\right)$	0	T < 4600 K
		(6±1)[-11]	(0.57±0.05)	0	T > 4600 K
7.	$N^+ + H_2 \rightarrow NH^+ + H$	(5.6±2.0)[-10]	0	0	

*It has been reported (source R-24) that it is not necessary in Reaction 1 to distinguish between $T_i(O^+)$ and $T_v(N_2)$, admittedly a surprising new result. Therefore, the rate parameters given are valid for $T = T_i$ or $T = T_v$.

**Cf. Reaction 10 of Table B.3.d-1, and its accompanying footnote.

Table B.3.d-2. (Continued)

No.	Reaction	a	b	c	Notes
8.a.	$O_2^+ + N \rightarrow NO^+ + O$	(1.8 ± 0.6) [-10]	0	0	
b.	$\rightarrow O^+ + NO$	-	-	-	Endothermic by 0.163 eV.
9.	$O_2^+ + N_2 \rightarrow NO^+ + NO$	$(1)\left(-16^{+1}_{-3}\right)$	0	0	Estd. values; source R-18A gives k < (1) [-15].
10.	$O_2^+ + NO_2 \rightarrow NO^+ + O_3$	0	0	0	Estd. values; k < (1) [-11]. Cf. Reaction 16 of Table B.3.d-1.
11.	$O_2^+ + H_2 \rightarrow$ Products	-	-	-	k < (1) [-11]
12.	$O_2^+ + Na \rightarrow NaO^+ + O$	(7.7 ± 3.0) [-11]	0	0	Cf. Reaction 17 of Table B.3.d-1.
13.a.	$N_2^+ + O \rightarrow NO^+ + N$	(1.4 ± 0.8) [-10]	0	0	Cf. Reaction 19 of Table B.3.d-1.
b.	$\rightarrow NO^+ + 0.5N(^4S) + 0.5N(^2D)$				Overall Reaction; estd. value.
14.	$N_2^+ + O_2 \rightarrow NO^+ + NO$	(1) $[-17 \pm 2]$	0	0	Estd. values; cf Reaction 21 of Table B.3.d-1.
15.	$N_2^+ + H_2 \rightarrow N_2H^+ + H$	(1.7 ± 0.3) [-9]	0	0	
16.	$N_2^+ + H_2O \rightarrow N_2H^+ + OH$	-	-	-	See Reaction 23 of Table B.3.d-1.

Table B.3.d-2. (Continued)

No.	Reaction	a	b	c	Notes
17.	$NO^+ + O_3 \rightarrow NO_2^+ + O_2$	-	-	-	k < (1) [-14]
18.	$N_3^+ + O_2 \rightarrow$ Products	(1.0±0.3) [-10]	0	0	Data at 200 K. Possible products include: (a) $NO^+ + O + N_2$; (b) $O_2^+ + N + N_2$; and (c) $NO_2^+ + N_2$, in roughly comparable magnitudes.
19.	$N_4^+ + O_2 \rightarrow N_2 + N_2 + O_2^+$	(4±1) [-10]	0	0	Data at 200 K.
20.	$O_2^+ \cdot N_2 + O_2 \rightarrow O_4^+ + N_2$	(1.0±0.5) [-9]	0	0	Estd. values.
21.	$O_2^+ \cdot N_2 + H_2O \rightarrow O_2^+ \cdot H_2O + N_2$	(4±2) [-9]	0	0	
22.	$O_2^+ \cdot O_2 + O \rightarrow O_2^+ + O_3$	(3±2) [-10]	0	0	
23.	$O_2^+ \cdot O_2 + NO \rightarrow NO^+ + O_2 + O_2$	(5) [-10]	0	0	Estd. values.
24.	$O_2^+ \cdot O_2 + H_2O \rightarrow O_2^+ \cdot H_2O + O_2$	(1.5±0.5) [-9]	0	0	
25.	$O_2^+ \cdot H_2O + O_2 \rightarrow O_2^+ \cdot O_2 + H_2O$	(2) [-10]	0	2300	Estd. values; k_{300} = (9.4) [-14]
26.	$O_2^+ \cdot H_2O + NO \rightarrow NO^+ + O_2 + H_2O$	(1) [-10]	0	0	Estd. values.
27.a.	$O_2^+ \cdot H_2O + H_2O \rightarrow H_3O^+ + OH + O_2$	(2.0±1.0) [-10]	0	0	

Table B.3.d-2. (Continued)

No.	Reaction	a	b	c	Notes
28.	$NO^+ \cdot NO + H_2O \rightarrow NO^+ \cdot H_2O + NO$	(1.4±0.3) [-9]	0	0	
29.	$NO^+ \cdot H_2O + NO \rightarrow NO^+ \cdot NO + H_2O$	(2) [-10]	0	2300	k_{300} = (9.4) [-14]
30.	$NO^+(H_2O)_3 + H_2O \rightarrow H_3O^+(H_2O)_2 + HNO_2$	(7±2) [-11]	0	0	
31.	$NO^+ \cdot CO_2 + H_2O \rightarrow NO^+ \cdot H_2O + CO_2$	(1.0±0.3) [-9]	0	0	
32.	$H_2O^+ + H_2O \rightarrow H_3O^+ + OH$	(1.8±0.3) [-9]	0	0	
33.	$H_3O^+ \cdot OH + H_2O \rightarrow H_3O^+ \cdot H_2O + OH$	(1.4±0.5) [-9]	0	0	
34.	$C^+ + O_2 \rightarrow CO^+ + O$	(1.1±0.3) [-9]	0	0	
35.	$C^+ + CO_2 \rightarrow CO^+ + CO$	(1.8±0.6) [-9]	0	0	
36.	$CO_2^+ + O \rightarrow CO + O_2^+$	(1.6±0.8) [-10]	0	0	Cf. Reaction 34 of Table B.3.d-1.
37.	$Fe^+ + O_3 \rightarrow FeO^+ + O_2$	(1.5±0.8) [-10]	0	0	
38.	$S^+ + O_2 \rightarrow SO^+ + O$	(1.6±0.3) [-11]	0	0	
39.	$U^+ + O_2 \rightarrow UO^+ + O$	$\left(8.5^{+4.0}_{-1.0}\right)$ [-10]	0	0	
40.	$U^+ + N_2 \rightarrow UN^+ + N$	-	-	-	k < (1) [-11] Not detected for kinetic energies < ≈ 5eV.
41.	$U^+ + NO \rightarrow UO^+ + N$	(1) $\left[-9^{+0}_{-1}\right]$	0	0	Estd. values.

Table B.3.d-3. Negative-ion charge transfer reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XV))

No.	Reaction	a	b	c	Notes
1.	$O^- + O_2(a\,^1\Delta_g) \rightarrow O_2^- + O$	-	-	-	Estd. k_{300} <(1) [-10] Cf. Reaction 3 of Table B.3.c-6.
2.	$O^- + O_3 \rightarrow O + O_3^-$	(5.3±2.0) [-10]	0	0	See Reaction 4 of Table B.3.c-6.
3.	$O^- + NO_2 \rightarrow O + NO_2^-$	(1.2±0.4) [-9]	0	0	
4.	$O_2^- + O \rightarrow O_2 + O^-$		-	-	Estd. k < (1) [-10]
5.	$O_2^- + O_3 \rightarrow O_2 + O_3^-$	(4.0±1.3) [-10]	0	0	
6.	$O_2^- + NO_2 \rightarrow O_2 + NO_2^-$	(8±3) [-10]	0	0	
7.	$O_2^- + NO_3 \rightarrow O_2 + NO_3^-$	(5) [-10]	0	0	Estd. values.
8.	$O_3^- + NO_2 \rightarrow O_3 + NO_2^-$	(2.8±1.0) [-10]	0	0	Products uncertain; Cf. Reaction 5 of Table B.3.d-4.
9.	$O_3^- + NO_3 \rightarrow O_3 + NO_3^-$	(5) [-10]	0	0	Estd. values.
10.	$NO^- + O_2 \rightarrow NO + O_2^-$	(5±2) [-10]	0	0	
11.	$NO_2^- + NO_3 \rightarrow NO_2 + NO_3^-$	(5) [-10]	0	0	Estd. values.

Table B.3.d-3. (Continued)

No.	Reaction	a	b	c	Notes
12.	$O_2^- \cdot H_2O + O_3 \rightarrow$ Products	(3.0±1.0)[-10]	0	0	
13.	$O_2^- (H_2O)_2 + O_3 \rightarrow$ Products	(3.4±1.0)[-10]	0	0	
14.	$H^- + NO_2 \rightarrow H + NO_2^-$	(2.9±1.0)[-9]	0	0	
15.	$OH^- + NO_2 \rightarrow OH + NO_2^-$	(1.0±0.3)[-9]	0	0	

Table B.3.d-4. Negative ion-atom interchange reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XVI))

No.	Reaction	a	b	c	Notes
1.	$O^- + N_2O \rightarrow NO^- + NO$	(2.3±0.5)[-10]	0	0	
2.	$O_3^- + O \rightarrow O_2^- + O_2$	$(1)\left[-11^{+1}_{-2}\right]$	0	0	No experimental data; estd. values.
3.	$O_3^- + N_2 \rightarrow N_2O^- + O_2$	-	-	-	k < (1)[-15]
4.	$O_3^- + NO \rightarrow NO_2^- + O_2$	(1.0±0.3)[-11]	0	0	

Table B.3.d-4. (Continued)

No.	Reaction	a	b	c	Notes
5.	$O_3^- + NO_2 \rightarrow NO_3^- + O_2$	(2±1) [-11]	0	0	Estd. values; Products uncertain; Cf. Reaction 8 of Table B.3.d-3.
6.	$O_3^- + CO_2 \rightarrow CO_3^- + O_2$	(4.0±1.2) [-10]	0	0	
7.	$O_3^- + H \rightarrow OH^- + O_2$	(8.4±4.0) [-10]	0	0	
8.	$NO_2^- + O \rightarrow$ Products	-	-	-	k < (1) [-11]
9.	$NO_2^- + N \rightarrow$ Products	-	-	-	k < (1) [-11]
10.	$NO_2^- + O_3 \rightarrow O_2 + NO_3^-$	(1.8±0.6) [-11]	0	0	
11.	$NO_2^- + NO_2 \rightarrow NO_3^- + NO$	(4.0±1.2) [-12]	0	0	Reverse Reactions (14, 15 of Table B.3.d-4) important.
12.	$NO_3^- + O \rightarrow$ Products	-	-	-	k < (1) [-11]
13.	$NO_3^- + N \rightarrow NO_2^- + NO$	-	-	-	k < (1) [-11]
14.	$NO_3^- + NO \rightarrow NO_2^- + NO_2$	-	-	-	k < (1) [-12] See Reactions 11, 15 of Table B.3.d-4.
15.	$OONO^- + NO \rightarrow NO_2^- + NO_2$	(1.5) [-11±1]	0	0	See Reactions 11, 14 of Table B.3.d-4.
16.	$O_2^- \cdot O_2 + O \rightarrow O_3^- + O_2$	(4±2) [-10]	0	0	$2O_2 + O^-$ may be a minor product channel.

Table b.3.d-4. (Continued)

No.	Reaction	a	b	c	Notes
17.	$O_2^- \cdot O_2 + NO \rightarrow OONO^- + O_2$	(2.5±0.8) [-10]	0	0	
18.	$O_2^- \cdot O_2 + H_2O \rightarrow O_2^- \cdot H_2O + O_2$	(1.4±0.4) [-9]	0	0	
19.	$O_2^- \cdot O_2 + CO_2 \rightarrow CO_4^- + O_2$	(4.3±1.3) [-10]	0	0	
20.	$O_2^- \cdot H_2O + NO \rightarrow OONO^- + H_2O$	(3.1±1.0) [-10]	0	0	
21.	$O_2^- \cdot H_2O + CO_2 \rightarrow CO_4^- + H_2O$	(5.8±1.0) [-10]	-0	0	
22.	$CO_3^- + O \rightarrow O_2^- + CO_2$	(8.0±2.4) [-11]	0	0	See Reaction 14 of Table B.3.c-6.
23.	$CO_3^- + NO \rightarrow NO_2^- + CO_2$	(9.0±3.0) [-12]	0	0	
24.	$CO_3^- + NO_2 \rightarrow NO_3^- + CO_2$	(8.0±3.0) [-11]	0	0	
25.	$CO_4^- + O \rightarrow CO_3^- + O_2$	(1.5±0.8) [-10]	0	0	$CO_2 + O_3^-$ may be a minor product channel
26.	$CO_4^- + O_2 \rightarrow O_4^- + CO_2$	(4.3) [-10]	0	3000	Estd. values; k_{300} = (2.0) [-14]
27.	$CO_4^- + NO \rightarrow OONO^- + CO_2$	(4.8±2.0) [-11]	0	0	

Table B.3.d-5. Radiation-stabilized positive-ion-neutral association reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XVII))

No.	Reaction	a	b	c	Notes
1.	$X^+ + Y \rightleftarrows (XY^+)^{\ddagger} \rightarrow XY^+ + h\nu$	(1)[-19.0±0.5]	0	0	Monatomic reactants
		(1)[-15.0±0.5]	0	0	Diatomic reactants
		(1)[-13.0±0.5]	0	0	Polyatomic and complex reactants
		(Estd. values)			

Table B.3.d-6. Three-body positive-ion-neutral association reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XIX))

No.	Reaction	a	b*	c	Notes
1.	$O^+ + N_2 + M \rightarrow NO^+ + N + M$	(5.4)[-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$T_{ref} = 82$ K; M = He; Apparently N_2O^+ predissociates.
2.	$N^+ + N_2 + M \rightarrow N_3^+ + M$	(1.8±0.2)[-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = N_2$
3.	$O_2^+ + O_2 + M \rightarrow O_4^+ + M$	(2.8)[-30]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$T_{ref} = 307$ K; $M = O_2$.
4.	$O_2^+ + N_2 + M \rightarrow O_2^+ \cdot N_2 + M$	(8±4)[-31]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$T_{ref} = 200$ K; M = He.

*All values of "b" estimated.

Table B.3.d-6. (Continued)

No.	Reaction	a	b*	c	Notes
5.	$O_2^+ + H_2O + M \rightarrow O_2^+ \cdot H_2O + M$	(1.9) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}=296 K; M = O_2.
6.	$N_2^+ + N_2 + M \rightarrow N_4^+ + M$	(5.0) [-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = N_2.
7.	$NO^+ + N_2 + M \rightarrow NO^+ \cdot N_2 + M$	(2) [-31]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = NO.
8.	$NO^+ + NO + M \rightarrow NO^+ \cdot NO + M$	(5.0) [-30]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = NO.
9.	$NO^+ + H_2O + M \rightarrow NO^+ \cdot H_2O + M$	(1.5) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = N_2.
10.a.	$NO^+ + CO_2 + M \rightarrow NO^+ \cdot CO_2 + M$	(3) [-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}=200 K; M = N_2.
b.		(2) [-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = CO_2.
11.	$NO^+ \cdot H_2O + H_2O + M \rightarrow NO^+(H_2O)_2 + M$	(1.1) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = N_2.

*All values of "b" estimated.

Table B.3.d-6. (Continued)

No.	Reaction	a	b*	c	Notes
12.	$NO^+(H_2O)_2 + H_2O + M \rightarrow NO^+(H_2O)_3 + M$	(1.6) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = N_2$.
13. a.	$H_3O^+ + H_2O + M \rightarrow H_3O^+ \cdot H_2O + M$	(3.7) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}=307 K; $M = O_2$.
b.		(3.4) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = N_2$.
14. a.	$H_3O^+ \cdot H_2O + H_2O + M \rightarrow H_3O^+(H_2O)_2 + M$	(2.0) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}= 307 K; $M = O_2$.
b.		(2.3) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = N_2$.
15 a.	$H_3O^+(H_2O)_2 + H_2O + M \rightarrow H_3O^+(H_2O)_3 + M$	(2.0) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}=307 K; $M = O_2$.
b.		(2.4) [-27]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = N_2$.
16.	$H_3O^+(H_2O)_3 + H_2O + M \rightarrow H_3O^+(H_2O)_4 + M$	(9.0) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	T_{ref}= 307 K; $M = O_2$.

*All values of "b" estimated.

Table B.3.d-7. Positive-ion collisional dissociation reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$.* (Source: R-24, Table 1 (XX))

No.	Reaction	a	b	c	Notes
1.	$O_2^+ \cdot O_2 + M \rightarrow O_2^+ + O_2 + M$	(2.4 ± 1.2) [-6]	(-1)	4900,	$k_{300} = (2.0 \pm 1.0)$ [-13]; $M = O_2$.
2.	$NO^+ \cdot NO + M \rightarrow NO^+ + NO + M$	(4) [-5 ± 1]	(-1)	7300 ±1000	$k_{300} = (9 \pm 2)$ [-16]; $M = NO$.
3.	$H_3O^+ \cdot OH + M \rightarrow H_3O^+ + OH + M$	(3) [-3 ± 2]	(-1)	12,000	$k_{300} = (1)$ [-20]; bonding energy lies between 0.77 and 1.52 eV.
4.	$H_3O^+ \cdot H_2O + M \rightarrow H_3O^+ + H_2O + M$	(8.8 ± 1.3) [0]	(-1)	18,000	$k_{300} \cong (7)$ [-26]; $M = N_2$.
5.	$H_3O^+(H_2O)_2 + M \rightarrow H_3O^+ \cdot H_2O + H_2O + M$	(8.0 ± 3.2) [-2]	(-1)	11,000	$k_{300} = (1.0 \pm 0.4)$ [-17]; $M = N_2, O_2$.
6.	$H_3O^+(H_2O)_3 + M \rightarrow H_3O^+(H_2O)_2 + H_2O + M$	$\left(5.0^{+5.0}_{-2.5}\right)$ [-2]	(-1)	8600	$k_{300} = \left(2^{+2}_{-1}\right)$ [-14]; $M = N_2, O_2, NO$.
7.	$H_3O^+(H_2O)_4 + M \rightarrow H_3O^+(H_2O)_3 + H_2O + M$	(7.6 ± 1.2) [-1]	(-1)	7700	$k_{300} = (6)$ [-12]; $M = O_2$.

*In this section, the "a" parameters have been obtained by back-calculation from measured or estimated values of "c" and of the rate constant at or very near 300 K, i.e., k_{300} (experimental). The "b" parameter has been uniformly estimated as equal to (-1).

Table B.3.d-8. Radiation-stabilized negative-ion-neutral association reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXI))

No.	Reaction	a	b	c	Notes
1.	$O^- + O_2 \rightarrow O_3^- + h\nu$	(1) [-17±2]	0	0	Estd. value.

Table B.3.d-9. Negative-ion photodissociation reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXII))

No.	Reaction	a	b	c	Notes
1.	$O_2^- \cdot O_2 + h\nu \rightarrow O_2^- + O_2$	(2) [0±3]	0	0	Cf. Reaction 4 of Table B.3.c-2.*

*Reaction 4 of Table B.3.c-2 and Reaction 1 of Table B.3.d-9 are probably indistinguishable, but Reaction 1 of Table B.3.d-9 is thought to dominate.

Table B.3.d-10. Three-body negative-ion-neutral association reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXIII))

No.	Reaction	a	b*	c	Notes
1.	$O^- + O_2 + M \rightarrow O_3^- + M$	(1.1±0.1) [-30]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$
2.	$O^- + N_2 + M \rightarrow N_2O^- + M$	(3) [-31]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$T_{ref} = 200$ K; M = He.
3.	$O^- + NO + M \rightarrow NO_2^- + M$	(1) [-29±2]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	Estd. values; Reaction 7 of Table B.3.c-6 is dominant.
4.	$O^- + H_2O + M \rightarrow O^- \cdot H_2O + M$	(1.0) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$
5.	$O^- + CO_2 + M \rightarrow CO_3^- + M$	(8.0) [-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = CO_2$
6.	$O_2^- + O_2 + M \rightarrow O_4^- + M$	(3.5±0.5) [-31]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$

*All values of "b" estimated.

Table B.3.d-10. (Continued)

No.	Reaction	a	b*	c	Notes
7.	$O_2^- + N_2 + M \rightarrow O_2^- \cdot N_2 + M$	(3) [-32]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$T_{ref} = 200$ K; M = He.
8.	$O_2^- + H_2O + M \rightarrow O_2^- \cdot H_2O + M$	(3) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$
9.	$O_2^- + CO_2 + M \rightarrow CO_4^- + M$	(2.0) [-29]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$
10.	$O_3^- + H_2O + M \rightarrow O_3^- \cdot H_2O + M$	(2.1) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	M = NO
11.	$NO_2^- + H_2O + M \rightarrow NO_2^- \cdot H_2O + M$	(1.3) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$
12.	$O_2^- \cdot H_2O + H_2O + M \rightarrow O_2^-(H_2O)_2 + M$	(4) [-28]	$\left(-1.0^{+0.5}_{-1.0}\right)$	0	$M = O_2$

*All values of "b" estimated.

Table B.3.d-11. Negative-ion collisional dissociation reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$.* (Source: R-24, Table 1 (XXIV))

No.	Reaction	a	b	c	Notes
1.	$O_2^- \cdot O_2 + M \rightarrow O_2^- + O_2 + M$	(2.0±1.2) [-5]	(-1)	6300	k_{300} = (1.7±1.0) [-14]; $M = O_2$.

*See footnote of Table B.3.d-7.

NOTES

Table B.3.e-1. Radiation-stabilized neutral recombination reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (XXV))

No.	Reaction	a	b	c	Notes
1.a.	$O + O \rightarrow O_2\left(A^3\Sigma_u^+\right) \rightarrow O_2 + h\nu$ (Herzberg)	(2.4±0.1) [-21]	0	0	
b.	$\rightarrow O_2\left(b^1\Sigma_g^+\right) \rightarrow O_2 + h\nu$ (Atmospheric)	(1.7±0.2)[-37] n_{N_2}	0	0	
c.	$\rightarrow O_2\left(B^3\Sigma_u^-\right) \rightarrow O_2 + h\nu$ (Schumann-Runge)	(2) [-27]	0	12,100±1100	
2.a.	$O + N \rightarrow NO\left(A^2\Sigma^+\right) \rightarrow NO + h\nu$ (gamma)	$\left\{1.2 \times 10^{-17}\left(\frac{T}{300}\right)^{-0.35} + 2.1 \times 10^{-34} n_{N_2}\left(\frac{T}{300}\right)^{-1.24}\right\}$			
b.	$\rightarrow NO\left(B^2\Pi_r\right) \rightarrow NO + h\nu$ (beta)	(3.1±0.1) [-34] n_{N_2}	(-1.4)	0	
c.	$\rightarrow NO\left(C^2\Pi\right) \rightarrow NO + h\nu$ (delta)	(6.8±3.0) [-18]	(-0.35)	0	
3.	$O + NO \rightarrow NO_2 + h\nu$	(8±2) [-17]	(-2.0±0.5)	0	p≥0.3 torr
		(7±2) [-18]	(-2.0±0.5)	0	$p \leq 10^{-3}$ torr
4.	$N + N \rightarrow N_2 + h\nu$	(1.0±0.5) [-17]	(-0.90±0.05)	0	

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Table B.3.e-2. Three-body neutral recombination reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXVII))

No.	Reaction	a	b	c	Notes
1.	$O + O + O \rightarrow O_2 + O(^1S)$	(1.5) [-34±1]	0	0	
2.	$O + O + O_2 \rightarrow O_2(A^3\Sigma_u^+) + O_2$	(3) [-33.0±0.3]	0	0	T = 1000 K
3.a.	$O + O + N_2 \rightarrow O_2 + N_2$	(3.0) [-33]	(-2.9±0.4)	0	
		(3.9) [-34]	(-2.5±0.5)	0	T_{ref} = 3000 K
b.	$\rightarrow O_2(A^3\Sigma_u^+) + N_2$	(2.1) [-37±1]	0	0	
c.	$\rightarrow O_2(b^1\Sigma_g^+) + N_2$	(1.7) [-37±1]	0	0	
4.a.	$N + N + N_2 \rightarrow N_2 + N_2$	(7.6±2.0) [-34]	0	-500±200	k_{300} = (4.0) [-33]
		(4.6±0.2) [-33]	(-1.7)	0	T_{ref} = 3000 K
b.	$\rightarrow N_2 + N_2(B^3\Pi)$	(1.4) [-33±1]	0	0	
5.	$N + O + O \rightarrow NO + O(^1S)$	(3) [-33±1]	0	0	
6.	$N + O + N_2 \rightarrow NO + N_2$	(1.1±0.3) [-32]	(-0.5±0.2)	0	
7.	$N + O + N_2 \rightarrow NO(B^2\Pi) + N_2$	(1) [-34±1]	0	0	
8.	$O + O_2 + N_2 \rightarrow O_3 + N_2$	(1.1) [-34]	0	-500±200	k_{300} = (6.0) [-34]
9.	$O + N_2 + M \rightarrow N_2O + M$	(1) [-34±2]	0	7500	Estd. value; k_{300} = (1.4) [-45]

Table B. 3. e-2. (Continued)

No.	Reaction	a	b	c	Notes
10.	$O + NO + N_2 \rightarrow NO_2 + N_2$	(1.0±0.1) [-31]	(-2.5±0.3)	0	
11.	$H + H + M \rightarrow H_2 + M$	(8.3) [-33.0±0.5]	(-0.6±0.2)	0	
12.	$H + O_2 + N_2 \rightarrow HO_2 + N_2$	(2.1±0.4) [-32]	0	-300±100	k_{300} = (5.5) [-32]
13.	$H + OH + M \rightarrow H_2O + M$	(7±4) [-32]	0	0	T = 2000 K
14.	$CO + O + N_2 \rightarrow CO_2 + N_2$	(1.4±0.3) [-35]	0	0	

Table B. 3. e-3. Neutral collisional dissociation reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXVIII))

No.	Reaction	a	b	c	Notes
1.	$O_2 + O_2 \rightarrow O + O + O_2$	(2.1±1.0) [-7]	(-1.5±0.5)	59,000	T = 3000-5000 K
2.	$N_2 + N_2 \rightarrow N + N + N_2$	(6.7±1.7) [-7]	(-1.6±0.5)	113,000	T = 8000-15,000 K
3.	$N_2 + Ar \rightarrow N + N + Ar$	(2.5±0.3) [-7]	(-1.6±0.5)	113,000	T = 8000-15,000 K
4.	$NO + M \rightarrow N + O + M$	(1.3±0.6) [-7]	(-1.5±0.5)	75,000	T = 3000-8000 K; M = Ar, O_2, N_2
5.	$O_3 + O_2(a\,^1\Delta_g) \rightarrow O + O_2 + O_2$	(4.5) [-11]	0	2800±200	T = 283-321 K; k_{300} = (4) [-15]

Table B.3.e-3. (Continued)

No.	Reaction	a	b	c	Notes
6.	$O_3 + O_2(b\,^1\Sigma_g^+) \rightarrow O + O_2 + O_2$	(2.5±0.5)[-11]	0	0	
7.	$O_3 + N_2 \rightarrow O + O_2 + N_2$	(6.4±1.6)[-10]	0	11,400	T = 200-1000 K; k_{300} = (2)[-26]

Table B.3.e-4. Neutral rearrangement reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXIX))

No.	Reaction	a	b	c	Notes
1.	$O + N_2 \rightarrow NO + N$	(1.0±0.3)[-10]	0	37,900±300	k_{300} = (1.1)[-65]
2.	$O + NO \rightarrow O_2 + N$	(5.3±1.1)[-12]	0	20,200±200	k_{300} = (3.1)[-41]
3.	$O + O_3 \rightarrow O_2 + O_2$	(1.5±0.3)[-11]	0	2240±200	k_{300} = (8.0)[-15]
4.	$O(^1D) + O_3 \rightarrow O_2 + O_2$	(2.5±1.0)[-10]	0	0	
5.	$O + NO_2 \rightarrow NO + O_2$	(9.1±2.0)[-12]	0	0	
6. a.	$O + N_2O \rightarrow NO + NO$	(1.5±0.5)[-10]	0	14,000±2000	k_{300} = (7.8)[-31]
b.	$\rightarrow O_2 + N_2$	(5±2)[-11]	0	14,000±2000	k_{300} = (2.6)[-31]
7.	$O(^1D) + H_2 \rightarrow OH + H$	(3.5)[-10±1]	0	0	
8.	$O + OH \rightarrow H + O_2$	(5±2)[-11]	0	0	Possibly b = 0.5
9.	$O + HO_2 \rightarrow OH + O_2$	-	-	-	k ≥ (1) [-11]; partially estd.

Table B.3.e-4. (Continued)

No.	Reaction	a	b	c	Notes
10.	$O(^1D) + H_2O \rightarrow OH + OH$	(2±1) [-10]	0	0	
11.	$N + O_2 \rightarrow NO + O$	(2.4±0.3) [-11]	0	4000±200	k_{300} = (3.9) [-17]
12.	$N(^2D) + O_2 \rightarrow NO + O$	(7.0±0.1) [-12]	(0.5)	0	
13.	$N + O_2(a^1\Delta_g) \rightarrow NO + O$	(2.0±0.8) [-14]	0	600	Products uncertain; k_{300} = (2.7) [-15]
14.	$N + NO \rightarrow N_2^{\ddagger} (v = 3\text{-}6) + O$	(2.2±0.6) [-11]	0	0	
15.	$N + O_3 \rightarrow NO + O_2$	(3.1±0.8) [-11]	(0.5)	1200	k_{300} = (5.7) [-13]
16.a.	$N + NO_2 \rightarrow N_2O + O$	(8±1) [-12]	0	0	Source R-19 gives a = (1.8±0.2) [-11] for overall reaction: $N + NO_2$ Products
b.	$\rightarrow NO + NO$	(6±1) [-12]	0	0	
c.	$\rightarrow N_2 + O + O$	(2±1) [-12]	0	0	
d.	$\rightarrow N_2 + O_2$	(2±1) [-12]	0	0	
17.	$NO + O_2 + NO \rightarrow NO_2 + NO_2$	(6.6±3.3) [-39]	0	-526	k_{300} = (3.8) [-38]
18.	$NO + O_3 \rightarrow NO_2 + O_2$	(9.5±1.0) [-13]	0	1300±100	k_{300} = (1.3) [-14]
19.a.	$NO_2 + O_3 \rightarrow NO_3 + O_2$	(9.8) [-12]	0	3500±300	Values given are for the overall reaction: $NO_2 + O_3 \rightarrow$ Products; k_{300} = (8.5) [-17]
b.	$\rightarrow NO + O_2 + O_2$				

Table B.3.e-4. (Continued)

No.	Reaction	a	b	c	Notes
20.a.	$H + O_3 \rightarrow OH + O_2$	(2.6±0.5)[-11]	0	0	
b.	$\rightarrow HO_2 + O$				
21.	$H + OH \rightarrow H_2 + O$	(1.2±0.4)[-11]	0	3650	k_{300} = (6.3)[-17]
22.a.	$H + HO_2 \rightarrow OH + OH$	(4.2)[-10.0±0.3]	0	950	k_{300} = (1.8)[-11]
b.	$\rightarrow H_2 + O_2$	(4.2)[-11.0±0.4]	0	350	k_{300} = (1.3)[-11]
23.	$H + H_2O_2 \rightarrow H_2 + HO_2$	(2.8)[-12.0±0.3]	0	1900	k_{300} = (5.0)[-15]
24.	$OH + O_3 \rightarrow HO_2 + O_2$	(1.3±0.4)[-12]	0	950	k_{300} = (5.5)[-14]
25.	$OH + OH \rightarrow H_2O + O$	(4.9±0.8)[-11]	0	400	k_{300} = (1.3)[-11]
26.	$OH + H_2 \rightarrow H_2O + H$	(3.6±1.3)[-11]	0	2590	k_{300} = (6.4)[-15]
27.	$OH + HO_2 \rightarrow H_2O + O_2$	-	-	-	$k \geq$ (1)[-11]
28.	$OH + H_2O_2 \rightarrow H_2O + HO_2$	(1.7±0.9)[-11]	0	910	k_{300} = (8.2)[-13]
29.	$HO_2 + HO_2 \rightarrow H_2O_2 + O_2$	(3.3±0.7)[-12]	0	0	
30.	$CO + OH \rightarrow CO_2 + H$	(9.3±1.3)[-13]	0	540±250	k_{300} = (1.5)[-13]

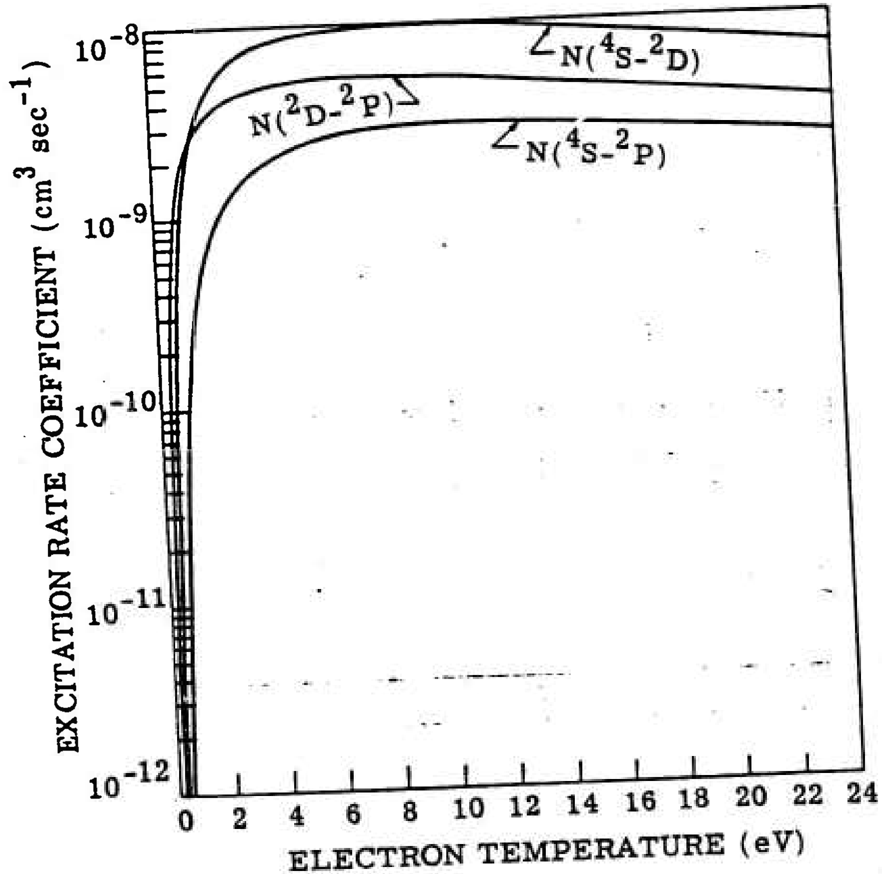

Figure B.3.f-1. Excitation of atomic nitrogen by electron impact. (Source: R-20, Figure 5)

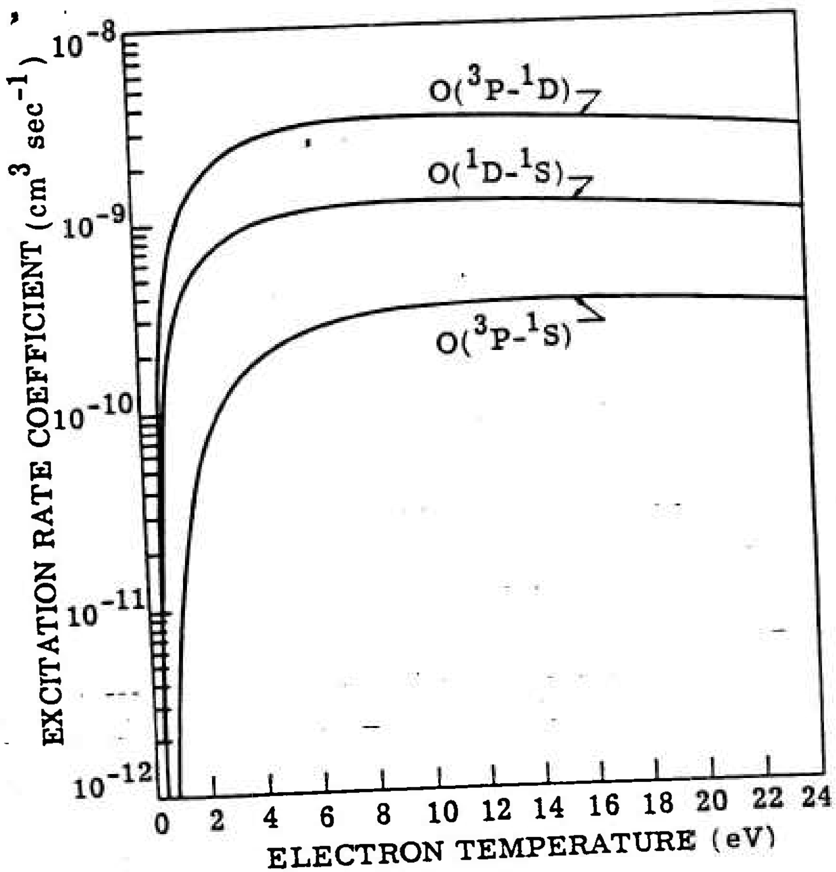

Figure B.3.f-2. Electron-impact excitation of atomic oxygen. (Source: R-20, Figure 9)

Table B.3.f-1. Quenching of $O(^1D)$ by various gases, relative to molecular nitrogen. (Cited from ten literature references) $\left(k_{N_2} \approx 8 \times 10^{-11} cm^3 sec^{-1}\right)$. (Source: R-20, Table 8)

Quencher	Literature Citation Number									
	1	2	3	4	5	6	7	8	9	10
He			0.077							
Ar		0.046		<0.036					<0.002	
Kr		0.25	0.35							
Xe	2.5	3.2	0.32							
N_2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CO_2		4.20	3.80	4.7	0.3	15.			4.35	0.038
H_2O		4.25	9.2	3.6		28.			5.0	
NO_2		6.75								
O_2	7.5			0.82	0.60	2.1	1.0	0.25	1.0	

Table B.3.f-2. Collisional excitation parameters. (Source: R-11, Table 2)

Originally Excited Species	Band Origin Wave Number, ν_o (cm^{-1})	Characteristic Temperature, $\theta = \frac{h\nu_o}{k}$ (K)	No. of Collisions Required to Bring About V-V Exchange:		No. of Collisions Required to Bring About T-V Exchange:	
			Z_{01}^{10}*	With Collision Partner	Z_{10}*	With Collision Partner
CO_2	667	959	--	--	4×10^5	N_2
CO_2	2349	3380	7×10^2	N_2	--	--
H_2O	1595	2295	$\sim 5 \times 10^3$	O_2	$\sim 2 \times 10^4$	Air
NO	1876	2700	5×10^5	N_2	--	--
NO(A)	2341	3371	7.9×10^2	N_2	--	--
CO	2143	3080	4.5×10^6	O_2	--	--
O_2	1556	2228	--	--	--	--
N_2	2331	3336	--	--	--	--

*The Z-values relate to ~300 K.

Table B.3.f-3. Effective line excitation cross-sections of the Meinel bands of N_2^+. (Source: R-14, Table 1)

Wavelength* (A)	v′, v″	E(eV)	$\sigma\left(10^{-19}cm^2\right)$**
6106	4, 0	100.	2.4; 1.4
6268	5, 1	100.	2.7
7240	5, 2	100.	0.6; 1.3
9145	1, 0	100.	110.
9431	2, 1	100.	58.
11036	0, 0	100.	80.

*The electronic transition for this sytem is $A^2\Pi_u \rightarrow X^2\Sigma_g^+$.

**Values cited from two different literature references.

Table B.3.f-4. Effective line excitation cross-sections of the 1st negative bands of N_2^+. (Source: R-14, Table 2)

Wavelength* (A)	v′ , v″	E (eV)	$\sigma(10^{-19} cm^2)$
3549	3,2	120.	0.50
3564	2,1	120.	1.1
3884	[illegible]	120.	6.1
		[illegible]00.	1.5
4199	2,3	120.	0.45
4236	1,2	120.	6.9
		400.	1.5
4652	1,3	120.	2.7
		400.	0.3
5149	1,4	120.	0.65
5228	0,3	120.	2.1
		400.	0.5

*The electronic transition for this system is $B^2\Sigma_u^+ \to X^2\Sigma_g^+$.

Table B.3.f-5. Quenching data for $N_2\left(A^3\Sigma_u^+\right)$. (Source: R-20, Table 4)

Quenchant	Rate Constant* $\left(cm^3 sec^{-1}\right)$
N_2	$< 3 \times 10^{-19}$
	$< 1.2 \times 10^{-18}$
O_2	$< 4 \times 10^{-10}$
	3.8×10^{-12}
O	$\leq 3 \times 10^{-11}$
N	5×10^{-11}
	5×10^{-12}
	5×10^{-11}
NO	7×10^{-11}

*More than one literature reference cited in some instances.

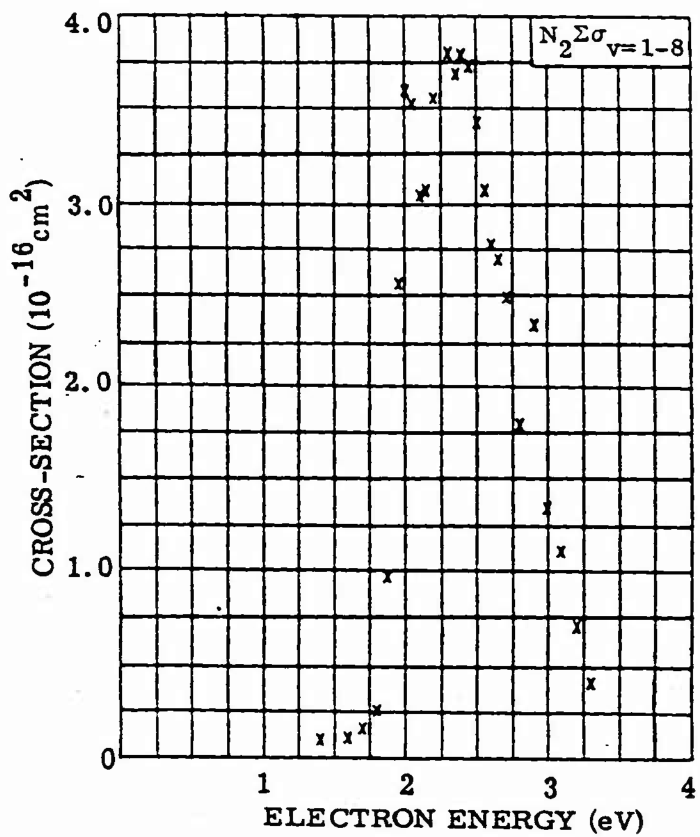

Figure B.3.f-3. (Source: R-14, Figure 40)

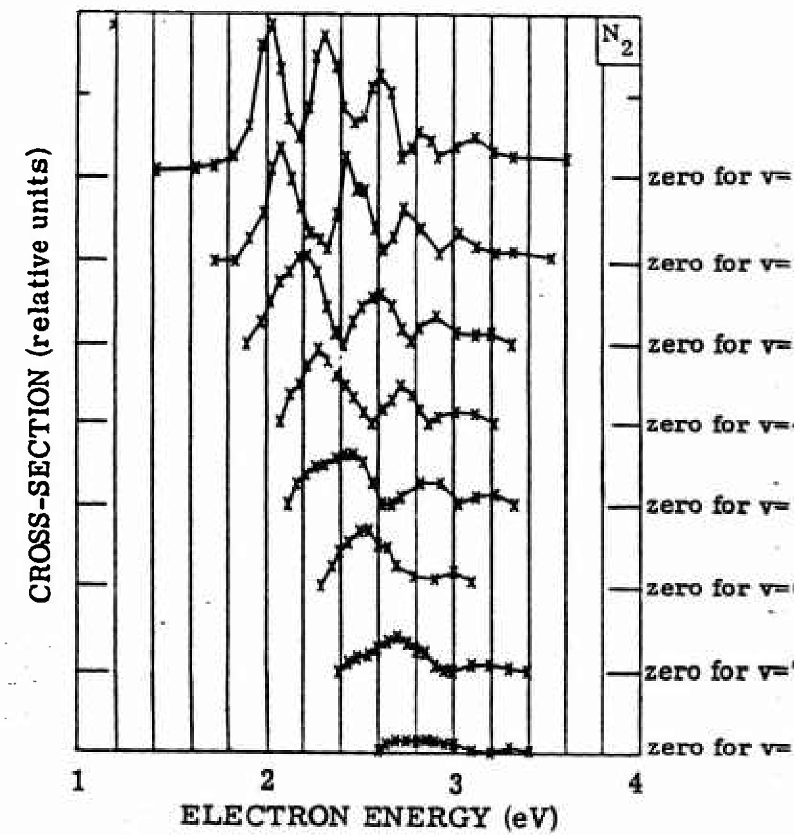

Figure B.3.f-4. (Source: R-14, Figure 41)

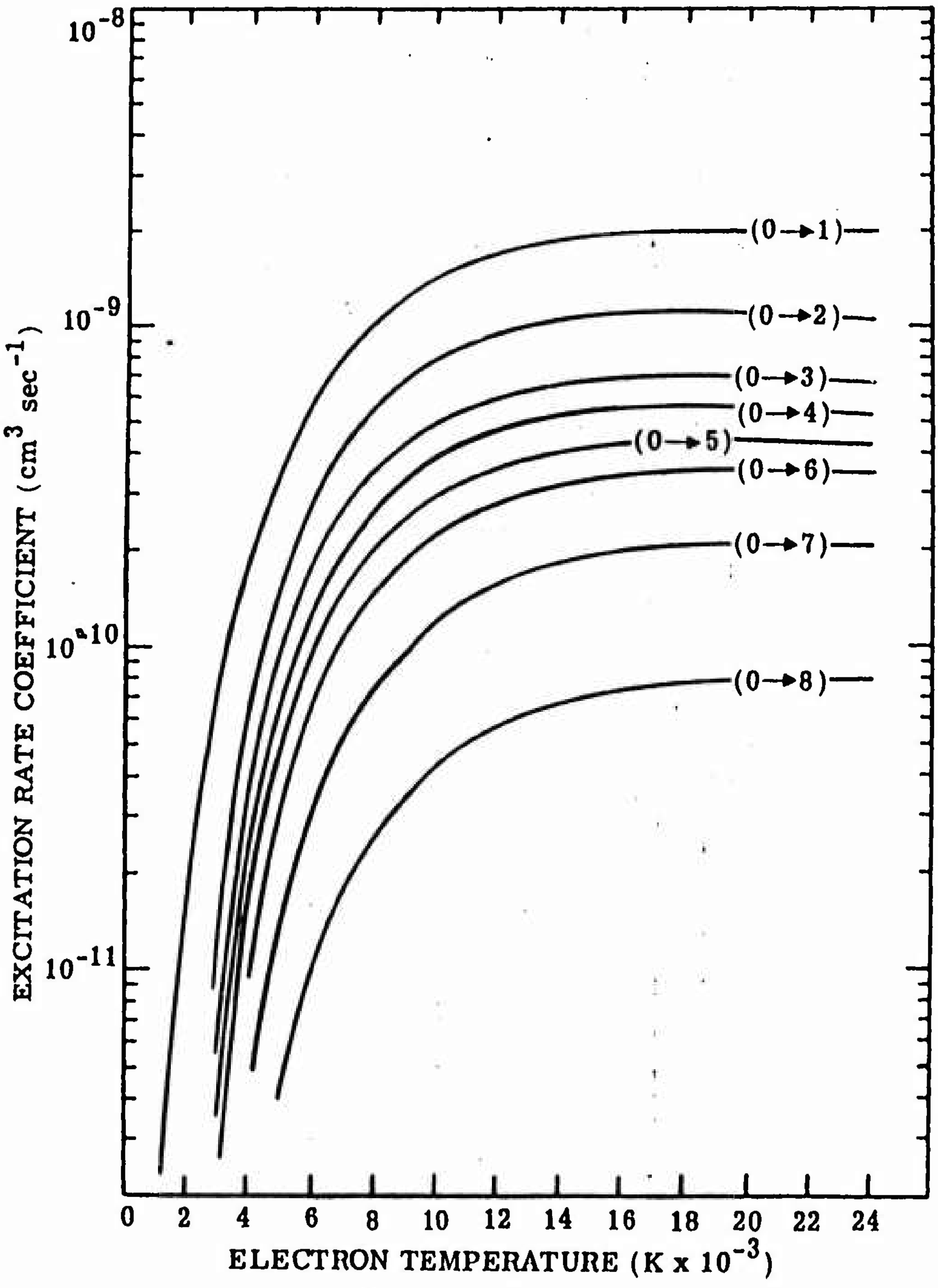

Figure B.3.f-5. Nitrogen vibrational excitation rate constants as a function of the electron kinetic temperature for 300 K N_2 kinetic temperature. (Source: R-20, Figure 3)

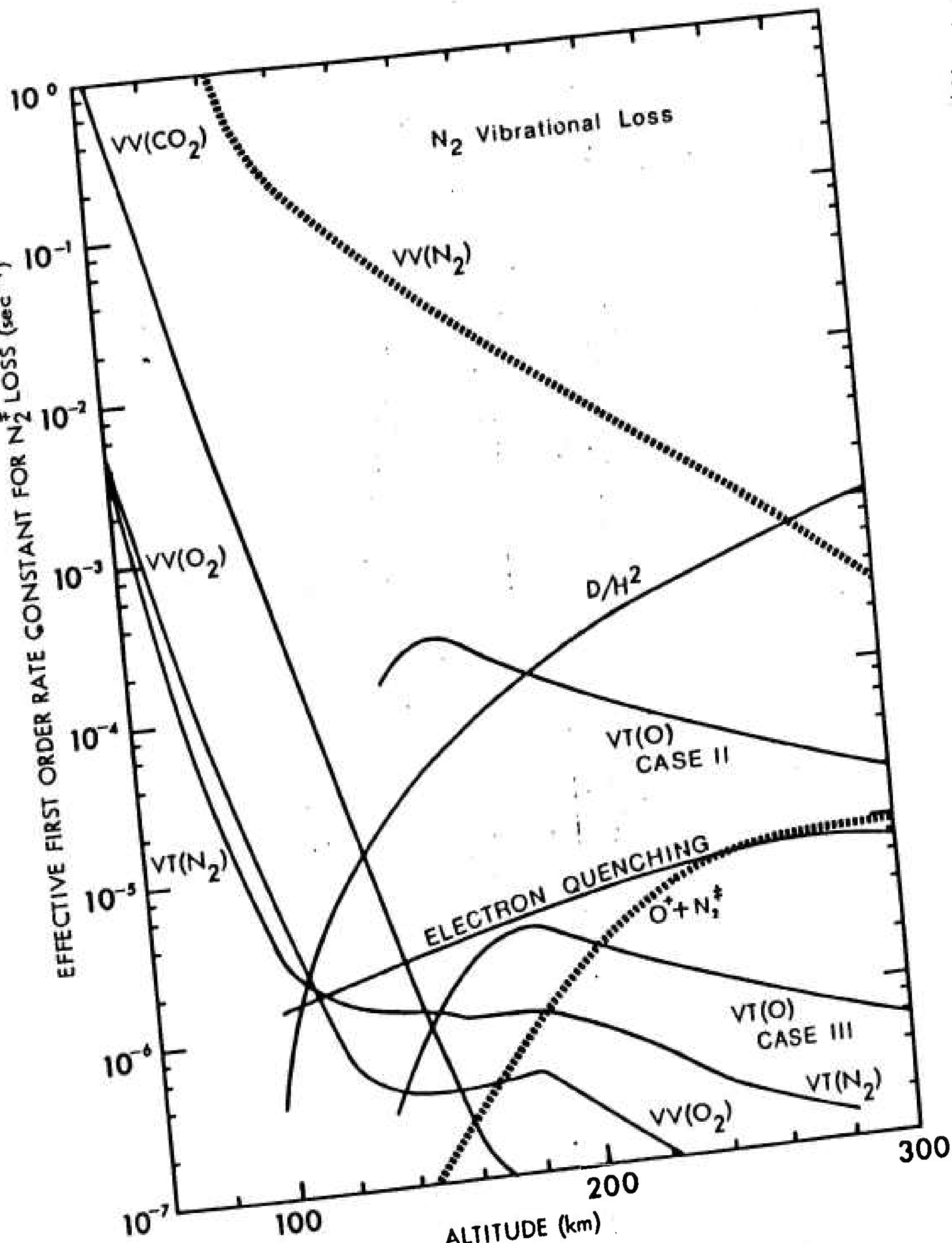

Figure B.3.f-6. Loss frequencies (sec^{-1}) for N_2 vibration as a function of altitude. (Source: R-20, Figure 4)

Table B.3.f-6. Energy transfer from $N_2^{\ddagger}$. (Source: R-20, Table 2)

Level, v	Collision Partner	Probable Product	Rate Constant $cm^3 sec^{-1}$	Temperature Range (K)
1	N_2	Kinetic Energy	$1.3 \times 10^{-11} T \exp\left(-220T^{-1/3}\right)$	300-5000
		$N_2^{\ddagger}$ (Resonant VV)	3×10^{-13}	300
1	O_2	Kinetic Energy	$\frac{2.5 \times 10^{-7} \exp\left(-263T^{-1/3}\right)}{[1-\exp(-3390/T)]}$	1000-10,000
		$O_2^{\ddagger}$ (Non-Resonant VV)		
1	O	Kinetic Energy	$\frac{6.21 \times 10^{-14} T \exp\left(-51.5T^{-1/3}\right)}{[1-\exp(-3990/T)]}$ $\frac{3.43 \times 10^{-12} T \exp\left(-152T^{-1/3}\right)}{[1-\exp(-3990/T)]}$	3000-4500
1	CO_2	$CO_2^{\ddagger}$ (Near Resonant VV)	$6 \times 10^{-13}\left(T/300\right)^{-1/2}$	300-1200
≥4	N_2O	$N_2O^{\ddagger}$	2.5×10^{-14}	300
≥1	Ar	Kinetic Energy	2.5×10^{-16}	300
1	NO	$NO^{\ddagger}$ (Non-Resonant VV)	1.5×10^{-16}	300

N.B.: The rate constants for VT in the above instance must be divided by $[1-\exp(-\theta_v/T)]$ to obtain rate equations of the conventional form.

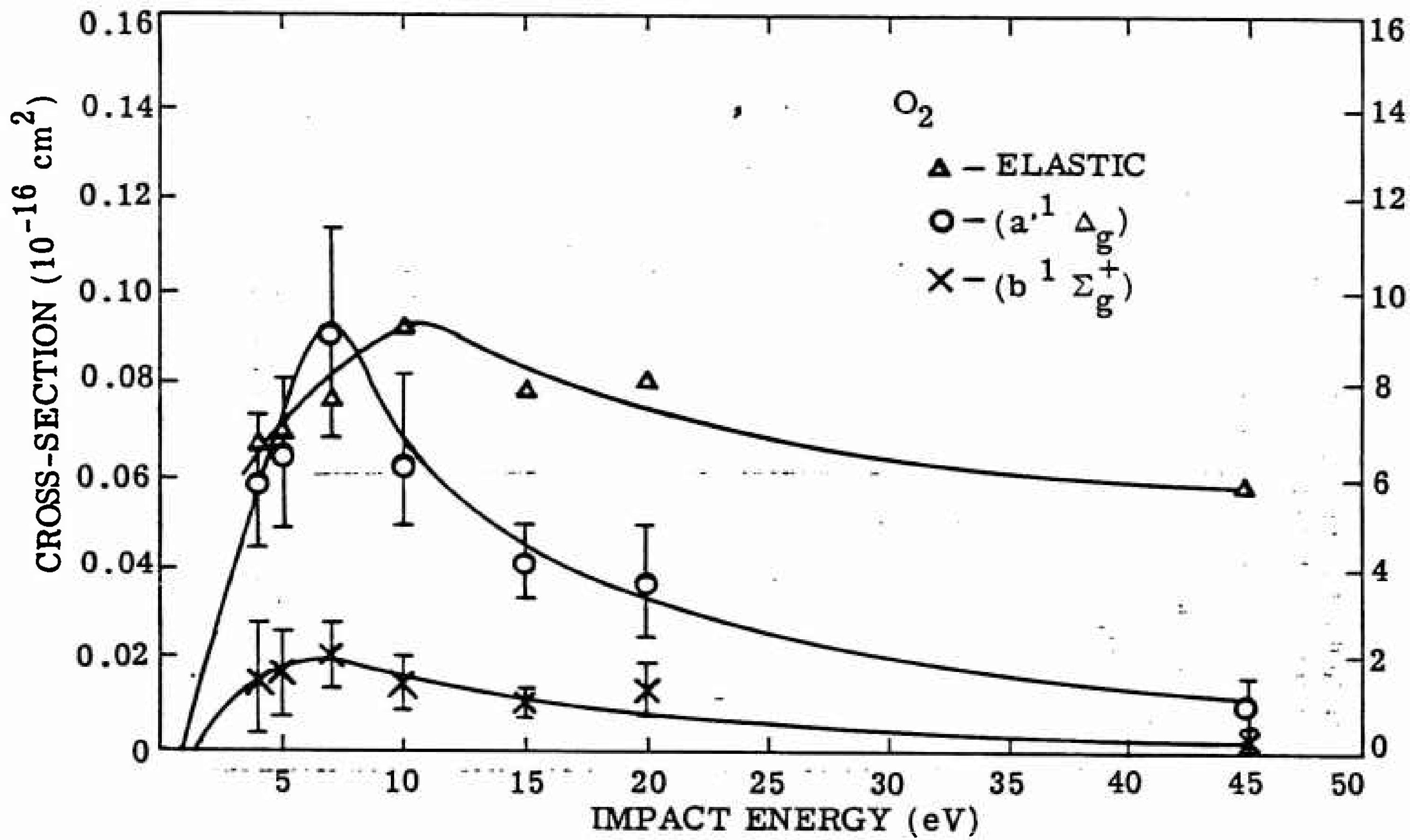

Figure B.3.f-7. Cross-section for electron-impact excitation of O_2.
(Source: R-20, Figure 8)

Table B.3.f-7. Quenching data for $O_2\left(^1\Delta_g\right)$.
(Source: R-20, Table 6)

Quenchant	Rate Constant* $\left(cm^3 sec^{-1}\right)$
O_2	2.4×10^{-18}
	2.2×10^{-18}
	2.2×10^{-18}
	2.0×10^{-18}
N_2	$< 1.1 \times 10^{-19}$
CO_2	3.9×10^{-18}
H_2O	1.5×10^{-17}
Ar	$\leq 2.1 \times 10^{-19}$
O	$\leq 1.3 \times 10^{-16}$
N	$(2.8 \pm 2) \times 10^{-15}$
O_3	3×10^{-15}

*More than one literature reference cited in some instances.

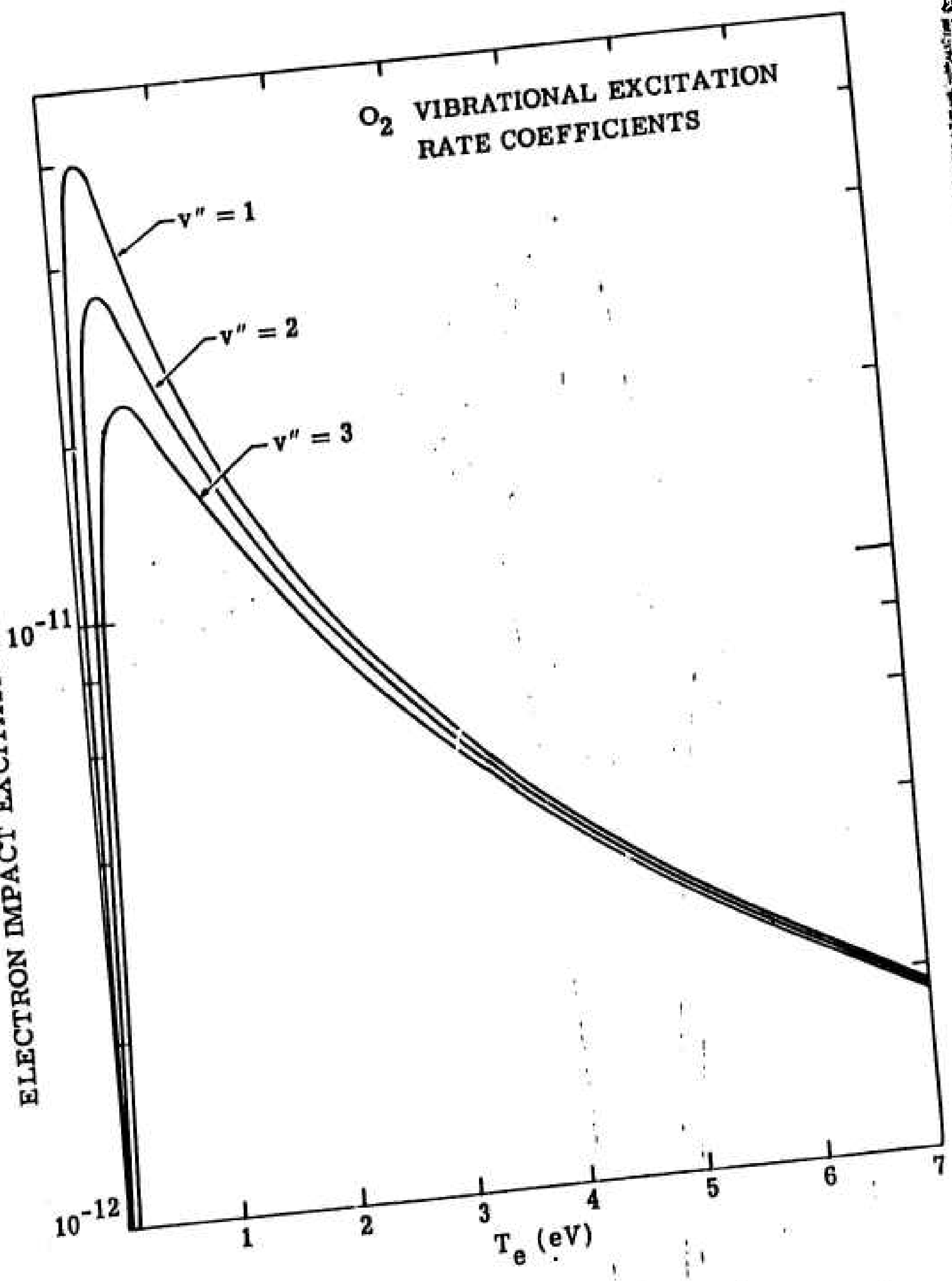

Figure B.3.f-8. The rate coefficient for O_2 vibrational excitation by electron impact. (Source: R-20, Figure 7)

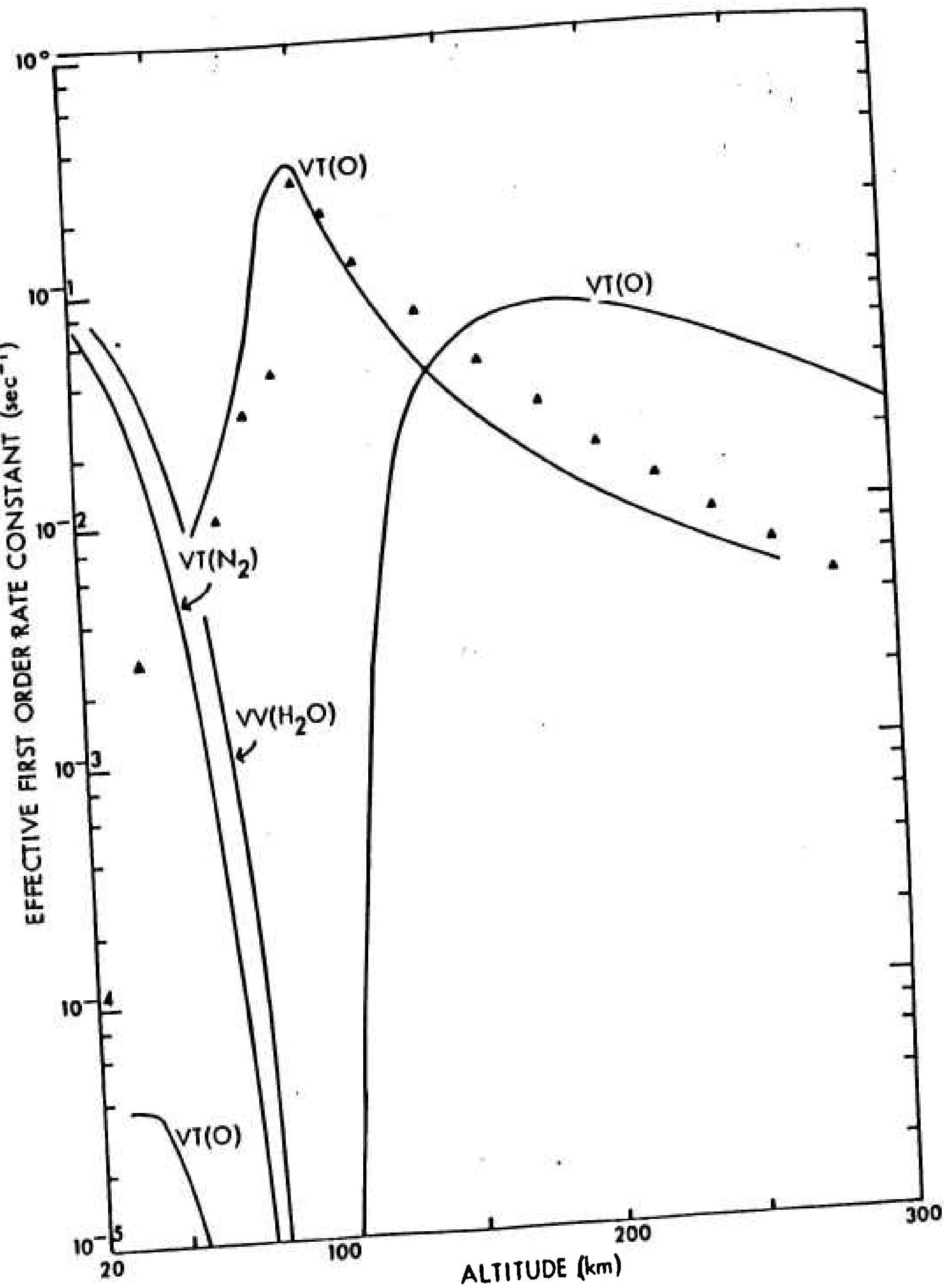

Figure B.3.f-9. (Deactivation of $O_2^{\dagger}$ (v = 1).
(Source: R-20, Figure 6)

Table B.3.f-8. Deactivation of $O_2^{\ddagger}$ (v = 1).
(Source: R-20, Table 5)

Reaction	Rate Constant, k_{10} $\left(cm^3\ sec^{-1}\right)$	T Range (K)
$O_2^{\ddagger} + M \rightarrow O_2 + M$ $M = N_2$ or O_2	$\dfrac{2.5 \times 10^{-12}\ T \exp\left[-\left(2.95 \times 10^6/T\right)\right]^{1/3}}{[1-\exp(-2270/T)]}$	800-3200
$O_2^{\ddagger} + O \rightarrow O_2 + O$	$3.3 \times 10^{-13}\ T^{1/2} \exp(-483/T)$ *	300-1700
	$1.7 \times 10^{-10} \exp(-4000/T)$	2000-4000
$O_2^{\ddagger} + H_2O \rightarrow O_2 + H_2O^{\ddagger}$	$10^{-(12\pm1)}\ (T/300)^{-1/2}$	

*Assuming that reaction occurs as fast as isotopic exchange.

Table B.3.f-9. Radiative electronic-state deexcitation reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXX))

No.	Reaction	a	b	c	Notes
1.	$O(^1D) \rightarrow O + h\nu$	(6.8±2.0)[-3]	0	0	
2.	$O(^1S) \rightarrow O + h\nu$	(1.35±0.4)[0]	0	0	Pressure-dependent
3.a.	$N(^2D)_{3/2} \rightarrow N + h\nu$	(1.6)[-5.0±0.3]	0	0	
b.	$N(^2D)_{1/2} \rightarrow N + h\nu$	(7.1)[-6.0±0.3]	0	0	
4.	$N(^2P) \rightarrow N + h\nu$	(7.7)[-2.0±0.3]	0	0	
5.	$O_2(a\,^1\Delta_g) \rightarrow O_2 + h\nu$	(2.6±1.0)[-4]	0	0	Pressure-dependent
6.	$O_2(b\,^1\Sigma_g^+) \rightarrow O_2 + h\nu$	(8.3)[-2.0±0.3]	0	0	
7.a.	$N_2(A\,^3\Sigma_u^+)(F_2) \rightarrow N_2 + h\nu$	(7.7)[-1.0±0.3]	0	0	
b.	$N_2(A\,^3\Sigma_u^+)(F_1, F_3) \rightarrow N_2 + h\nu$	(3.7)[-1.0±0.3]	0	0	
8.	$NO(a\,^4\Pi) \rightarrow NO + h\nu$	(6.3)[0.0±0.3]	0	0	
9.	$NO_2(^2B_1) \rightarrow NO_2 + h\nu$	(1.4±0.2)[+4]	0	0	
10.a.	$O^+(^2D)_{5/2} \rightarrow O^+ + h\nu$	(4.8)[-5.0±0.3]	0	0	
b.	$O^+(^2D)_{3/2}\quad O^+ + h\nu$	(1.7)[-4.0±0.3]	0	0	

Table B.3.f-9. (Continued)

No.	Reaction	a	b	c	Notes
11. a.	$O^+(^2P)_{3/2} \rightarrow O^+ + h\nu$	(2.4) [-1.0±0.3]	0	0	
b.	$O^+(^2P)_{1/2} \rightarrow O^+ + h\nu$	(1.9) [-1.0±0.3]	0	0	
12.	$N^+(^1D) \rightarrow N^+ + h\nu$	(4.0) [-3.0±0.3]	0	0	
13.	$N^+(^1S) \rightarrow N^+ + h\nu$	(1.1) [0.0±0.3]	0	0	

Table B.3.f-10. Collisional electronic-state quenching reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXXII))

No.	Reaction	a	b	c	Notes
1.	$O(^1D) + e \rightarrow O(^3P) + e$	(1.5) [-9±1]	0	0	For additional quenchants of $O(^1D)$, see Table B.3.f-1.
2.	$O(^1D) + O_2 \rightarrow O + O_2(b\,^1\Sigma_g^+)$	(7±2) [-11]	0	0	
3.	$O(^1D) + N_2 \rightarrow O + N_2$	(8.0±4.0) [-11]	0	0	
4.	$O(^1D) + CO_2 \rightarrow O + CO_2$	(3±1) [-12]	0	0	
5. a.	$O(^1S) + e \rightarrow O(^3P) + e$	(1.8) [-9±1]	0	0	Cf. Figure B.3.f-2.
b.	$\rightarrow O(^1D) + e$	(4) [-10±1]	0	0	
6.	$O(^1S) + O \rightarrow O + O$	(1.8±0.2) [-13]	0	0	

Table B. 3. f-10. (Continued)

No.	Reaction	a	b	c	Notes
7.	$O(^1S) + O_2 \rightarrow O + O_2$	(3±1) [-13]	0	0	
8.	$O(^1S) + N_2 \rightarrow O + N_2$	-	-	-	k < (1) [-17]
9.	$O(^1S) + H_2O \rightarrow O + H_2O$	(3±2) [-1[illegible]]	0	0	
10.	$O(^1S) + CO_2 \rightarrow O + CO_2$	(3. 3±0. 3) [-13]	0	0	
11.	$O^+(^2D) + e \rightarrow O^+ + e$	(1) [-7±2]	0	0	
12.	$N(^2D) + e \rightarrow N + e$	(5) [-10±1]	0	0	
13.	$N(^2D) + N_2 \rightarrow N + N_2$	-	-	-	k ≤ (6) [-15]
14.*	$O_2(a\,^1\Delta_g) + e \rightarrow O_2 + e$	(1) [-11±1]	0	0	Detailed balance calculation; partially estd. values
15.*	$O_2(a\,^1\Delta_g) + O \rightarrow O_2 + O$	-	-	-	k ≤ (1) [-16]
16.*	$O_2(a\,^1\Delta_g) + O_2 \rightarrow O_2 + O_2$	(2. 4±0. 2) [-18]	0	0	
17.*	$O_2(a\,^1\Delta_g) + O_2(a\,^1\Delta_g) \rightarrow O_2 + O_2(b\,^1\Sigma_g^+)$	(2) [-18±1]	0	0	
18.*	$O_2(a\,^1\Delta_g) + N_2 \rightarrow O_2 + N_2$	-	-	-	k < (1.1) [-19]
19.*	$O_2(a\,^1\Delta_g) + O_3 \rightarrow O_2 + O_3$	(3±2) [-15]	0	0	

*For additional quenchants of $O_2(a\,^1\Delta_g)$, see Table B. 3. f-7.

Table B.3.f-10. (Continued)

No.	Reaction	a	b	c	Notes
20.	$O_2(b\,^1\Sigma_g^+) + O_2 \rightarrow O_2 + O_2$	(4.5±4.0)[-16]	0	0	
21.	$O_2(b\,^1\Sigma_g^+) + N_2 \rightarrow O_2 + N_2$	(2.0±1.0)[-15]	0	0	
22.	$N_2(A\,^3\Sigma) + O \rightarrow N_2 + O$	-	-	-	k ≤ (3)[-11]
23.	$N_2(A\,^3\Sigma) + N \rightarrow N_2 + N$	(5) $\left[-11^{+0}_{-1}\right]$	0	0	
24.	$N_2(A\,^3\Sigma) + O_2 \rightarrow N_2 + O_2$	(3.8±2.0)[-12]	0	0	
25.	$N_2(A\,^3\Sigma) + NO \rightarrow N_2 + NO$	(7±4)[-11]	0	0	
26.	$N_2^+(A\,^2\Pi) + N_2 \rightarrow N_2^+ + N_2$	(1)[-9±1]	0	0	
27.	$N_2^+(B\,^2\Sigma) + O_2 \rightarrow N_2^+ + O_2$	(2)[-9±1]	0	0	
28.	$N_2^+(B\,^2\Sigma) + N_2 \rightarrow N_2^+ + N_2$	(6)[-10±1]	0	0	

Table B.3.f-11. Radiative vibrational-state deexcitation reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXXIII))

No.	Reaction	a	b	c	Notes
1.	$CO(v=1) \rightarrow CO(v=0) + h\nu$	(3.3±0.3)[+1]	0	0	
2.	$CO_2(001) \rightarrow CO_2(000) + h\nu$	(4.00±0.20)[+2]	0	0	

Table B.3.f-12. Collisional vibrational-state quenching reactions and suggested rate constants, $k = a(T/300)^b e^{-c/T}$. (Source: R-24, Table 1 (XXXIV))

No.	Reaction	a	b	c	Notes
1.	$O_2(v=1) + M \rightarrow O_2(v=0) + M$	$\dfrac{2.5 \times 10^{-12}\ T \exp[-(2.95 \times 10^6/T)]^{1/3}}{[1-\exp(-2270/T)]}$			$M = N_2$ or O_2; T = 800-3200 K
2.	$O_2(v=1) + O \rightarrow O_2(v=0) + O$	(5.7±3.0)[-12]	(-0.5)	483	T = 300-1700 K; k_{300} = (1.1)[-12]
		(1.7±0.5)[-10]	0	4000	T = 2000-4000 K
3.	$N_2(v=1) + O \rightarrow N_2(v=0) + O$	$\dfrac{6.21 \times 10^{-14}\ T \exp[-(1.37 \times 10^5/T)]^{1/3}}{[1-\exp(-3390/T)]}$ or $\dfrac{3.43 \times 10^{-12}\ T \exp[-(3.74 \times 10^6/T)]^{1/3}}{[1-\exp(-3390/T)]}$			T = 3000-4500 K
4.	$N_2(v=1) + N_2 \rightarrow N_2(v=0) + N_2$	$1.3 \times 10^{-11}\ T \exp[-(1.06 \times 10^7/T)]^{1/3}$			T = 300-5000 K

Table B.3.f-13. Collisional vibrational energy exchange reactions and suggested rate constants, $k = a(T/300)^{b} e^{-c/T}$. (Source: R-24, Table 1 (XXXV))

No.	Reaction	a	b	c	Notes
1.	$O_2(v=1) + H_2O \rightarrow O_2(v=0) + H_2O(010)$	(1.7) [-11±1]	(-0.5)	0	Endothermic by 39 cm^{-1} (~0.005 eV)
2.	$N_2(v=1) + O_2(v=0) \rightarrow N_2(v=0) + O_2(v=1)$	$\left\{\frac{2.5\times10^{-7}\exp[-(1.82\times10^{7}/T)]^{1/3}}{[1-\exp(-3390/T)]}\right\}$			T = 1000-10,000 K.
3.	$N_2(v=1) + N_2(v=0) \rightarrow N_2(v=0) + N_2(v=1)$	$(3)\left[-13.0^{+1.5}_{-0.3}\right]$	0	0	Case of resonant VV at T = 300 K.
4.	$N_2(v=1) + CO_2(000) \rightarrow N_2(v=0) + CO_2(001)$	(6±2) [-13]	(-0.5)	0	T = 300-1200 K.

SECTION C

RADIATION DATA

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Table C.1-1. Known airglow emissions for the earth. Production processes are: R, resonance scattering; F, fluorescence; C, chemical association; I, ionic reactions; e, photoelectrons; T, excitation transfer. Production rate factors are g and d; h_q is the quenching height. (Source: R-9, Table 5)

λ(Å)		Emitter State	DAY			TWILIGHT		NIGHT		
			Intensity	Height	Process	Intensity	Height	Intensity	Height	Process
1	304	He^+	Present		R			(4.8)		R
2	584	He	Present		R			(12)		
3	834	O^+	Present		R					
4	1025	H Ly β	Present	$300\text{-}10^4$	R			10 R	200	R
5	1200	$N(^4P)$	400 R	180	R?					
6	1216	H Ly α	6 kR	$100\text{-}10^5$	R			2 kR	$100\text{-}10^5$	R
7	1302-4-6	$O(^3S)$	7.5 kR	190	eFR					
8	1356	$O(^5S)$	350 R	140	e					
9	1300-1500	$N_2(a\Pi g)$	Present		e					
10	1493, 1744	N	Present		e					
11	2150 etc.	$NO(A^2\Sigma^+)$	1 kR	70-150	R					
12	3371 etc.	$N_2(C^3\Pi_u)$	6 kR	150 up	e					
13	2000-4000	$N_2(B^3\Sigma_u)$			e					
14	2600-3800	$O_2(A^3\Sigma_u^+)$						600 R	90	C
15	3466	$N(^2P)$	Present		e					
16	3889	$He(^3P)$			R	1 R	>400?			
17	3914 etc.	$N_2^+(B^2\Sigma_u^+)$	3.0 kR	150	RF	200-500 R	300	<1R		
18	3933, 68	$Ca^+(^2P)$				≤100 R	80-200			
19	4368	$O(4^3P)$				1 R				
20	5200	$N(^2D)$	90 R	~200	I	10 R		1 R	~250	I
21	5000-6500	HO_2?						1 R/A	~90	C
22	5577	$O(^1S)$	3.0 kR	90; 175	Ce	400 R	200?	250 R	90; 300	C, I
23	5893	$Na(^2P)$	30 kR	93	R	1-4 kR	93	20-150 R	~93	C
24	6300, 64	$O(^1D)$	3-30 kR	250	FIe	1 kR	300	100-500 R	300	I
25	6563	$H(3^2P)$						3 R	200	F
26	6708	$Li(^2P)$				10-1000 R	~90			
27	7619 etc.	$O_2(^1\Sigma)$	300 kR	40-130	RFT			6 kR		
28	7699	$K(^2P)$				40 R	~90			
29	7774, 8446	O	1.8, 1.1 kR	~150	e					
30	10510 etc.	$N_2(B^3\Pi_g)$	900 R	150	e					
31	10830	$He(^3P)$				3 kR	600			
32	11038 etc.	$N_2^+(A^2\Pi_u)$	4 kR	150	RF					
33	12700 etc.	$O_2(^1\Delta)$	20 MR	50	F	5 MR	80	80 kR	90?	C?
34	28000	$OH(v \le 9)$	4.5 MR		C			4.5 MR	90	C

Table C.1-1. (Continued)

	q (photons sec^{-1}	d(source)	h_q (km)	Remarks
1	1.1×10^{-4}			Nightglow radiation could be either or both.
2	1.7×10^{-5}			
3				
4	2.6×10^{-6}			
5				
6	2.1×10^{-3}	$\left(4.5 \times 10^{-8}[H_2]\right)$		
7	1.0×10^{-4}			
8				
9				Lyman-Birge-Hopfield
10				
11	4.0×10^{-6}			γ bands; g for 1-0 band
12				2nd positive
13				Vegard-Kaplan
14				Herzberg
15				
16	0.1			Scatterer is He(^{3}S)
17	.050	$10^{-8}[N_2]$	46	1st negative
18	0.3, 0.15			
19				
20	(6×10^{-11})		~200	Also quenched by electrons
21				Continuum
22	(1×10^{-11})	$3 \times 10^{-8}[O_2]$	94	2972A (5%)
23	0.80		40	
24	(4.5×10^{-10})	$5.8 \times 10^{-6}[O_2]$	340	
25	2.6×10^{-6}			
26	16			May be of artificial origin
27	6.3×10^{-9}	$\leq 5 \times 10^{-3}[O_3]$	90	Atmospheric
28	1.67			
29			37	1st positive
30			37	1st positive
31	16.8		~400	Scatterer is He(^{3}S); h_q for its destruction.
32	.042	2.8×10^{-8}		Meinel; g,d for 1-0 band (9200A)
33	(9.4×10^{-11})	$9.5 \times 10^{-3}[O_3]$	75	IR Atm; 0-1 band 1.58μ; Noxon bands 1.9μ
34				Meinel; 4.5μ to 3816A

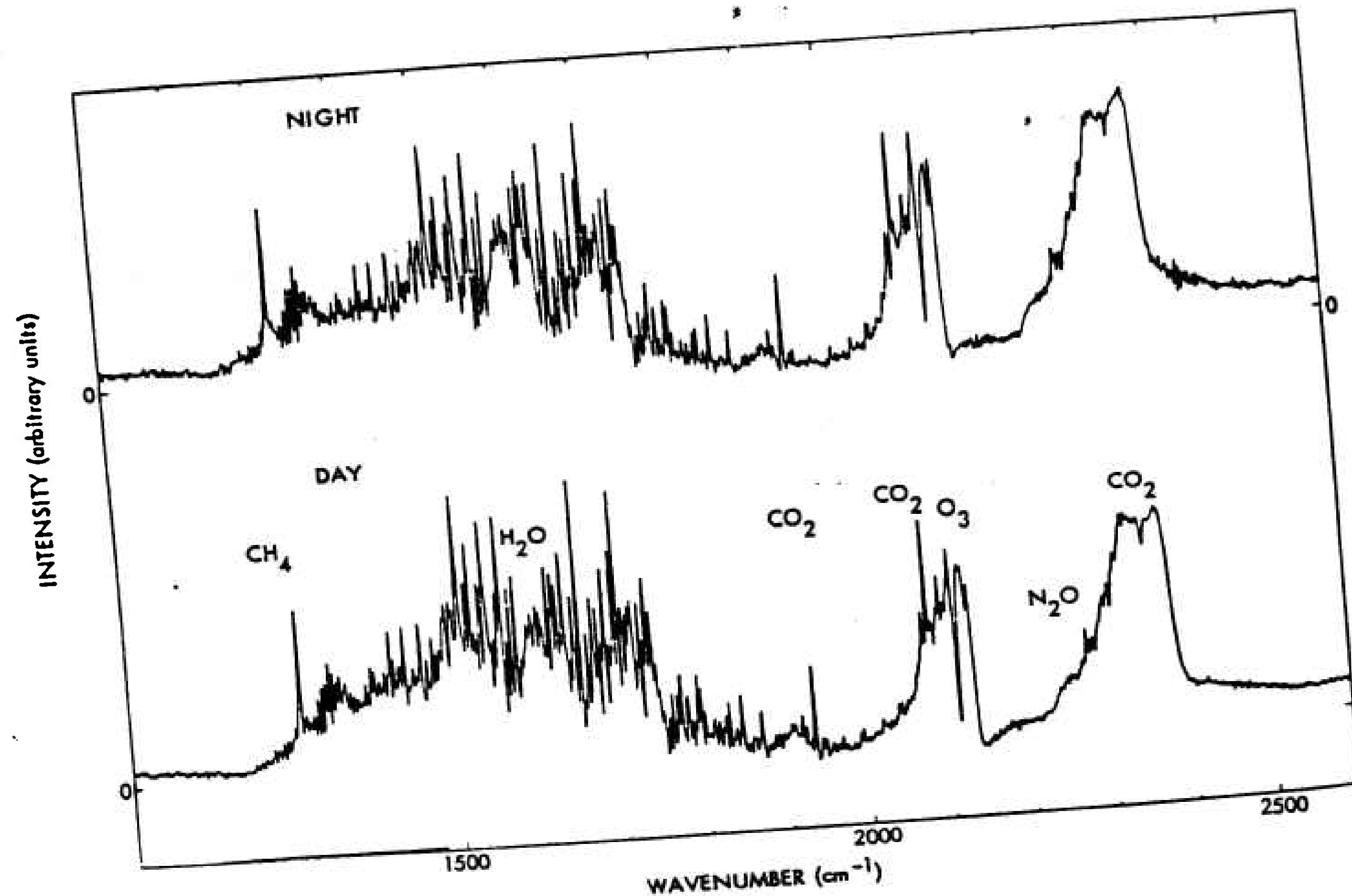

Figure C.1-1. Spectrum of the airglow between 4 and 8 μm.
(Source: R-11, Figure 1)

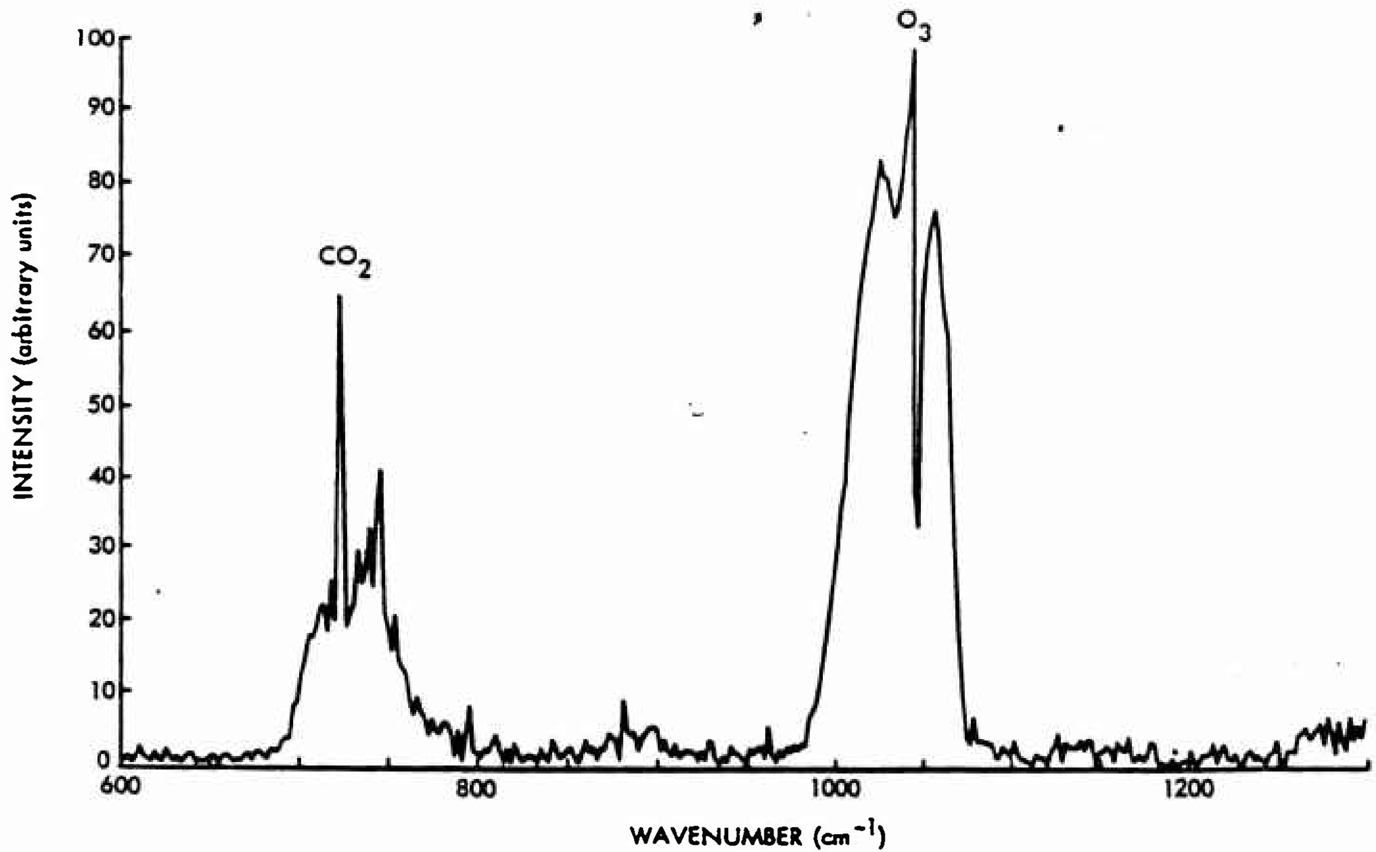

Figure C.1-2. Atmospheric emission spectrum between 8 and 16 μm (altitude $\approx$ 12 km). (Source: R-11, Figure 2)

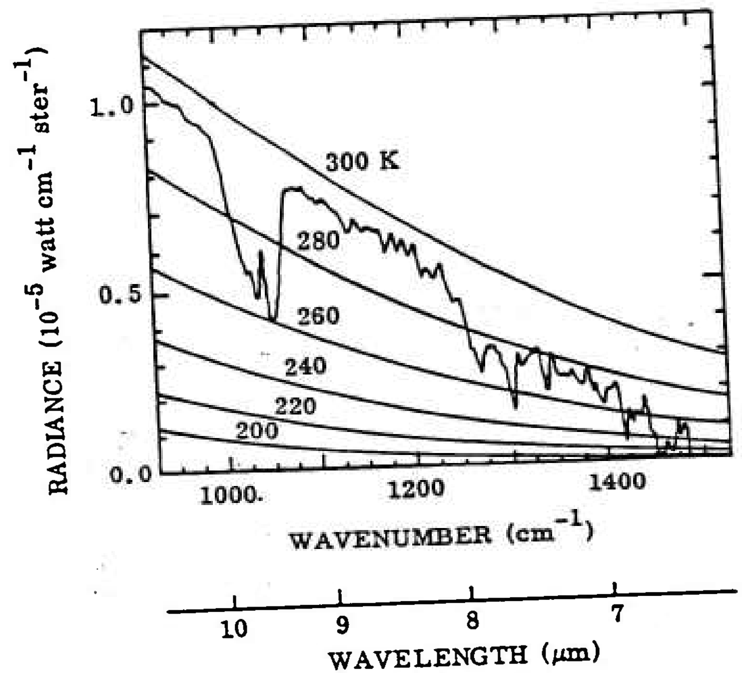

Figure C.1-3. Earthshine in the 1000-1450 cm^{-1} region. (Source: R-11, Figure 5)

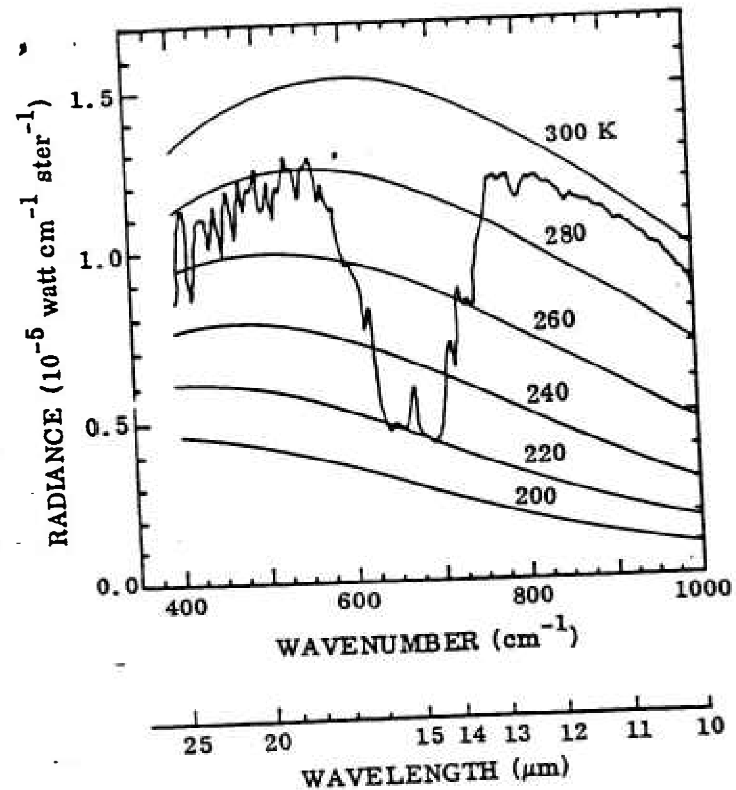

Figure C.1-4. Earthshine in the 400-1000 cm^{-1} region. (Source: R-11, Figure 6)

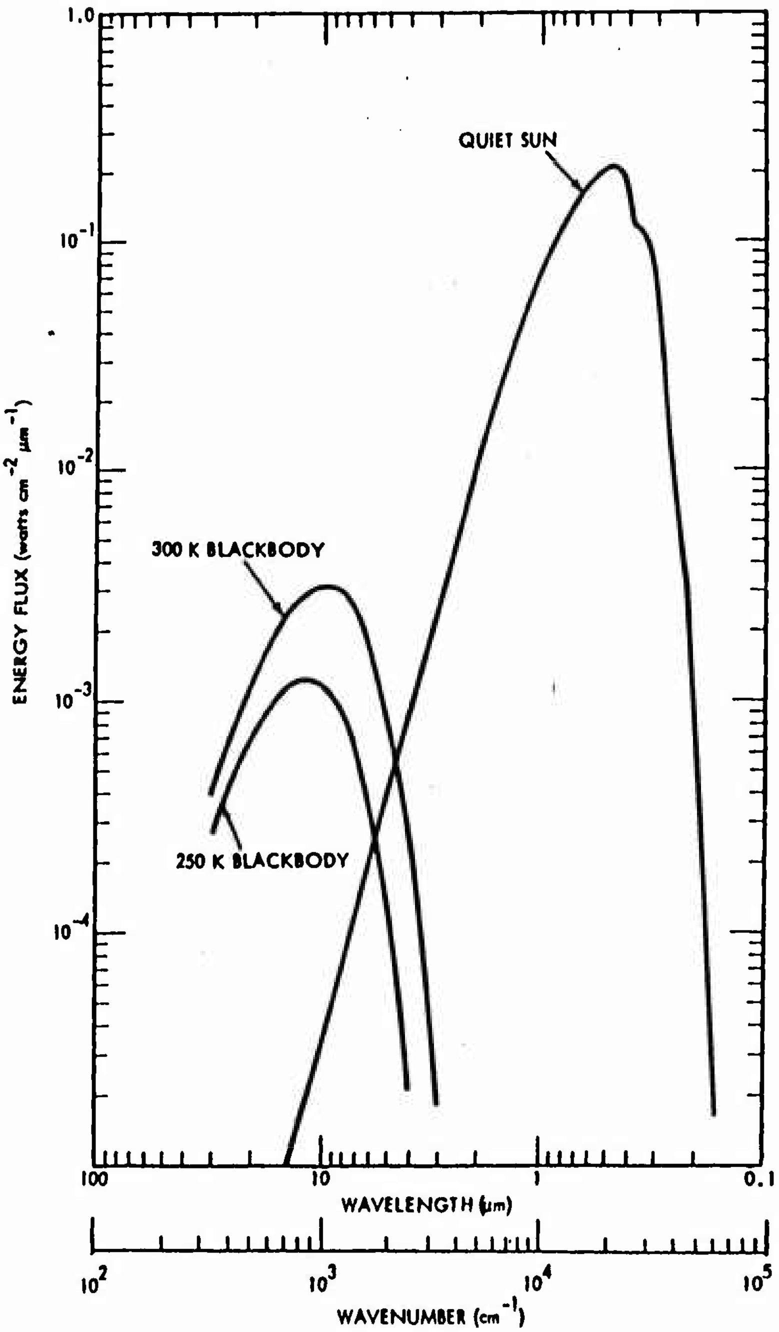

Figure C.1-5. Irradiance at the top of the atmosphere, for quiet sun and two blackbody sources. (Source: R-11, Figure 7)

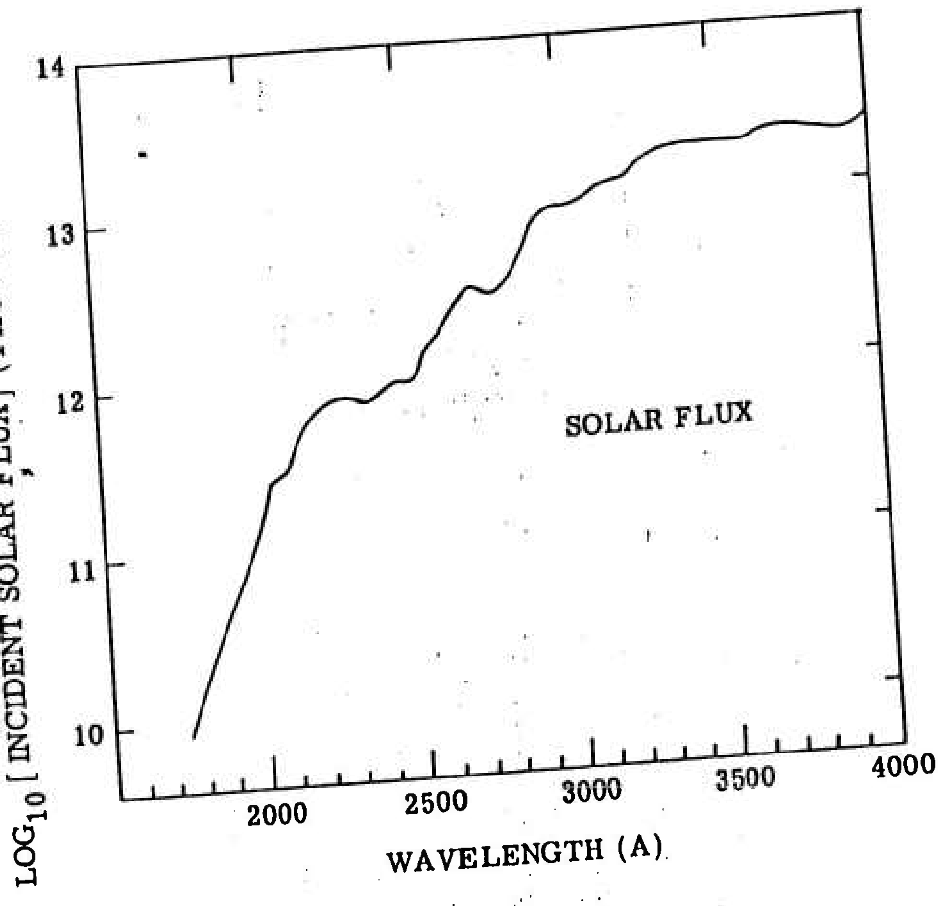

Figure C.1-6. Solar flux incident on upper atmosphere. Averaged over 50 A (4000-2650 A) ; 25 A (2600-2000 A) ; unaveraged (1950-1750 A). (Source: R-13, Figure 1)

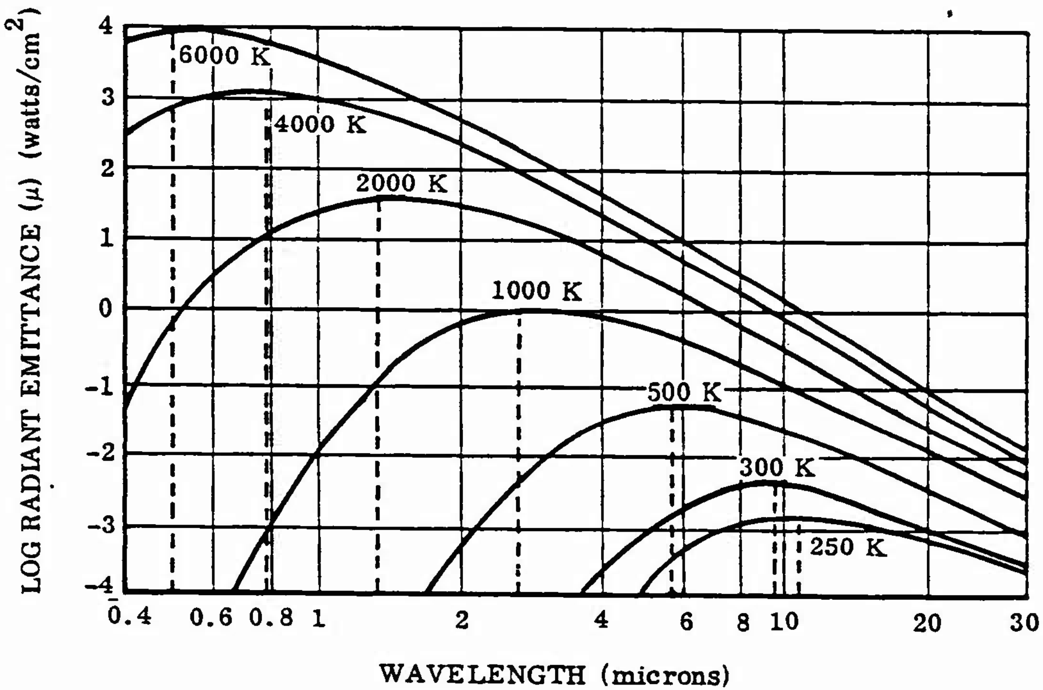

Figure C.1-7. Blackbody spectral emittance at various temperatures. (Source: S)

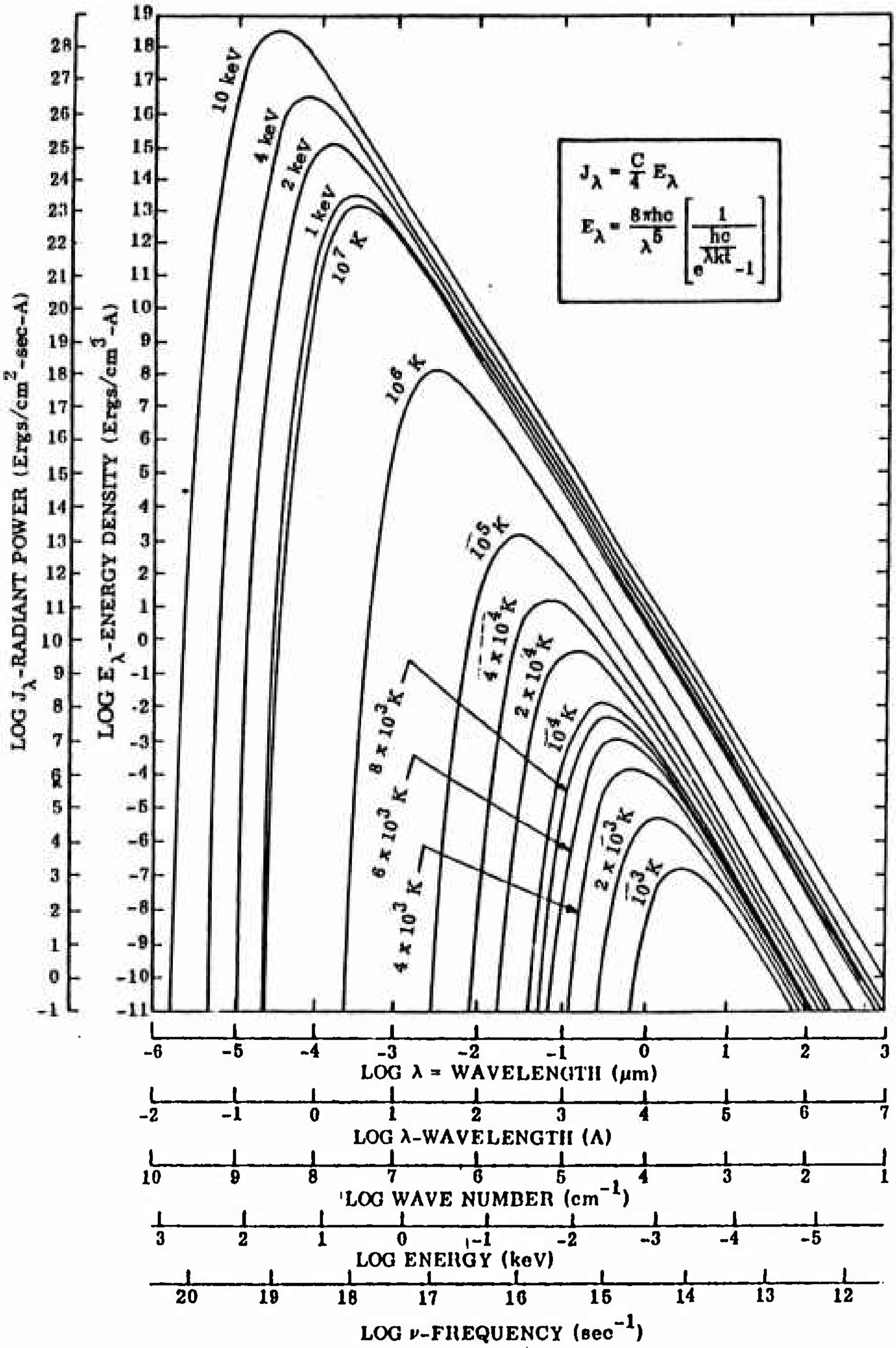

Figure C.1-8. Blackbody radiant power and energy density. (Source: L)

NOTES

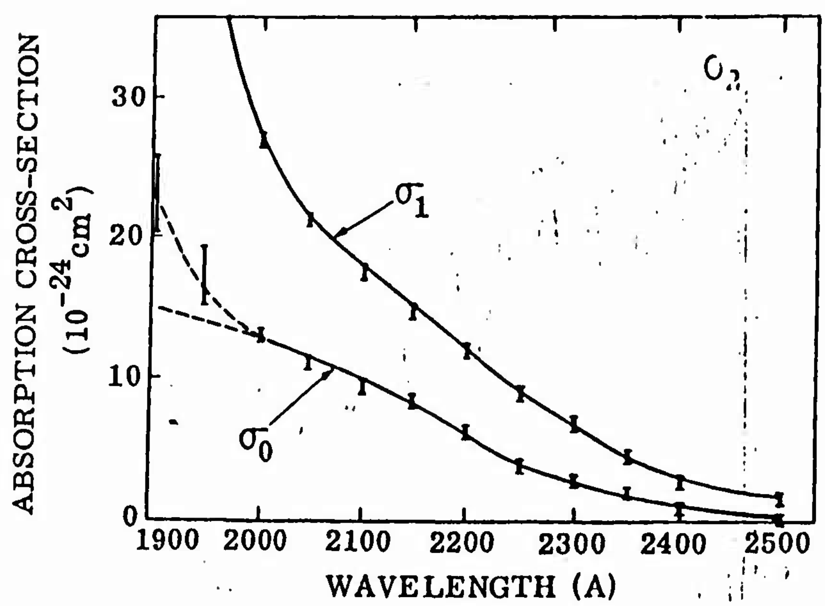

Figure C.2-1. Oxygen absorption cross-sections in the Herzberg continuum. The one-atmosphere cross-section is denoted by σ_1 and the extrapolated zero-pressure cross-section by σ_0. (Source: R-12, Figure 1)

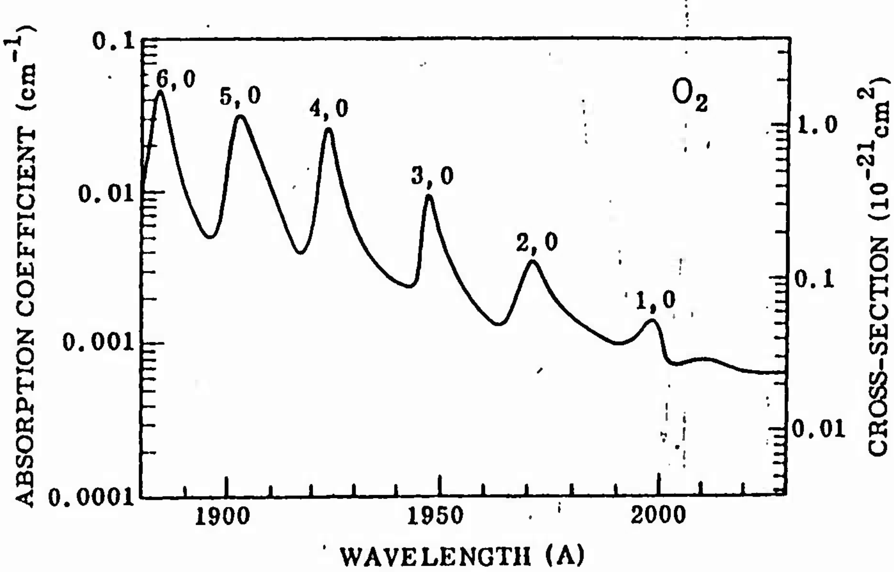

Figure C.2-2. Oxygen absorption cross-sections, Schumann-Runge bands (1, 0 to 6, 0). (Source: R-12, Figure 2)

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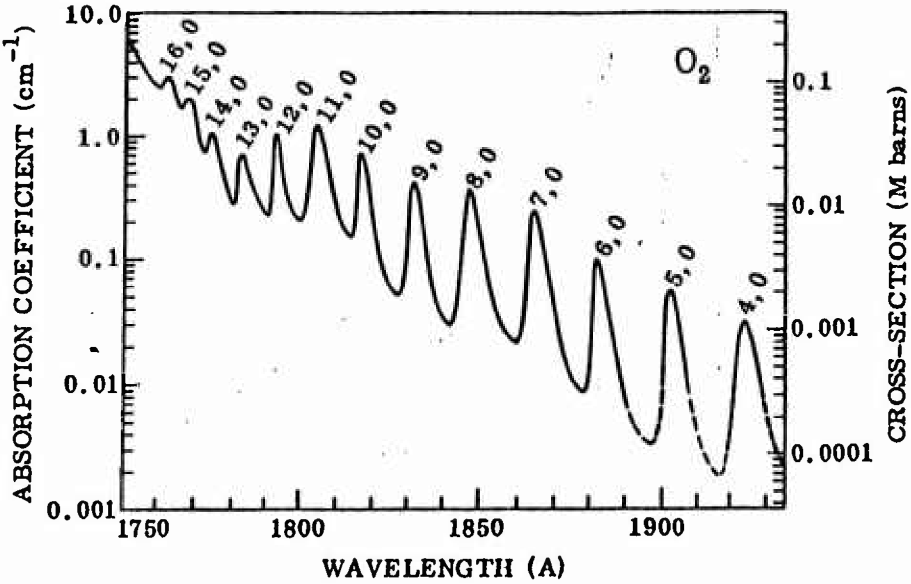


Figure C.2-3. Oxygen absorption cross-sections, Schumann-Runge bands (4, 0 to 16, 0). (Source: R-12, Figure 3)

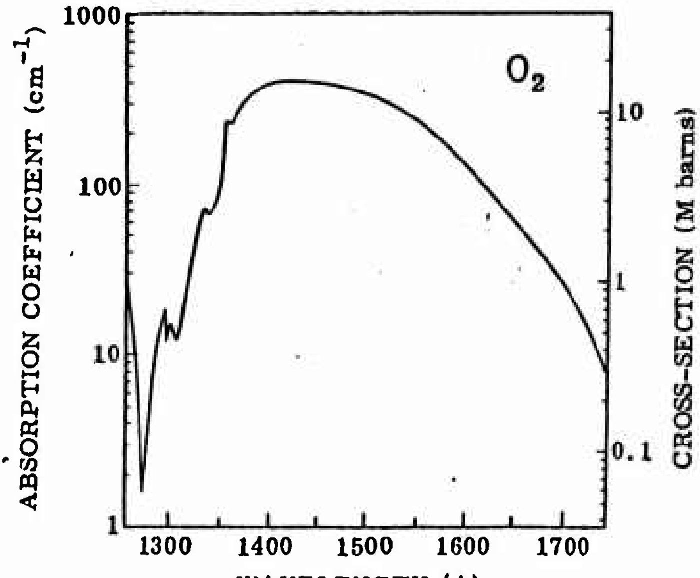


Figure C.2-4. Oxygen absorption cross-sections in the Schumann-Runge continuum. (Source: R-12, Figure 4)

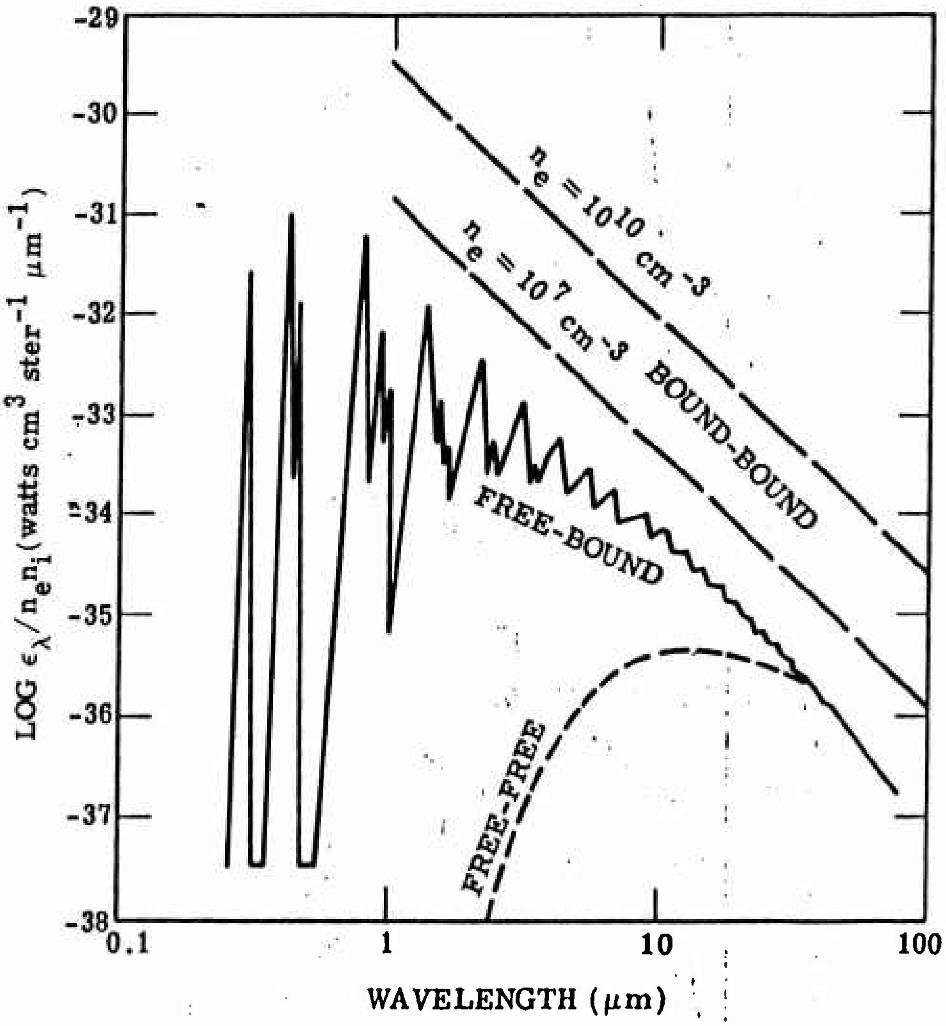


Figure C.2-5. Calculated emissivities of oxygen plasma at 500 K. (Source: R-11, Figure 8)

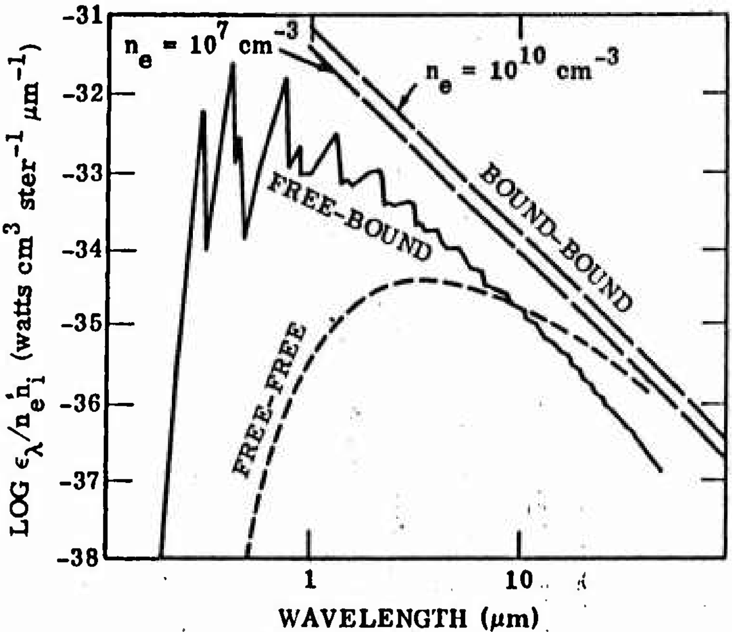


Figure C.2-6. Calculated emissivities of oxygen plasma at 2000 K. (Source: R-11, Figure 9)

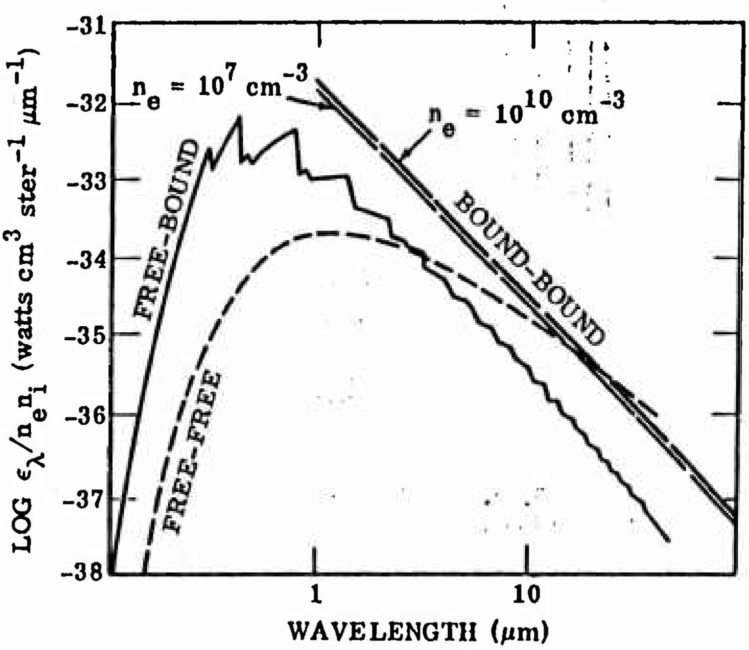


Figure C.2-7. Calculated emissivities of oxygen plasma at 6000 K. (Source: R-11, Figure 10)

Table C.2-1. Atomic oxygen lines which may absorb solar lines. Atomic oxygen resonance lines (1302, 1305, 1306 A) not included. (Source: R-12, Table 5)

Solar Line (A)	O I Line (A)	Classification
1025.7	1025.7	$^3P_2 - 3d\,^3D^o$
989.8	990.13	$^3P_1 - 3s'\ ^3D^o$
937.8	937.84	$^3P_2 - 7s'\ ^3S^o$
930.7	930.89	$^3P_1 - 7d\ ^3D^o$
835.3	835.44	$^1D_2 - 10d'\ ^1F^o,\ ^1D^o$
834.5	834.34	$^1D_2 - 12s'\ ^1D^o$
832.9	833.10	$^1D_2 - 12d'\ ^1F^o,\ ^1D^o$
787.7	788.18	$^1D_2 - 5s''\ ^1P^o$
770.4	770.35	$^3P_1 - 4d'\ ^3P_2{}^o$
761.1	761.26	$^1D_2 - 6d''\ ^1F^o,\ ^1D^o$
686.3	686.28	$^3P_1 - 5d''\ ^3P^o,\ ^3D^o$
685.5	685.54	$^3P_2 - 5d''\ ^3P^o,\ ^3D^o$

Table C.2-2. Data on infrared bands of atmospheric interest. (Source: R-11, Table 1 and additional material (L))

Species	Rotational Constant B	Transition	Band Origin: Wave Number, ν_o (cm^{-1})	Band Origin: Wavelength, λ_o (μm)	Band Strength, S ($cm^{-2}\ atm^{-1}$)	Einstein Coefficient, A (sec^{-1})	Oscillator Strength (f-Number)
CO_2	0.390	100-000	1388	--	Inactive	--	--
		010-000	667	15.00	223	2.77	8.95×10^{-6}
		001-000	2349	4.26	2590	400	1.14×10^{-4}
		101-000	3715	2.69	45.4	17.6	1.97×10^{-6}
		201-000	4978	2.01	0.95	0.659	4.0×10^{-8}
		001-100	961	10.4	--	0.2	5.79×10^{-7}
H_2O	27.877	100-000	3652	2.74	21.9	8.17	9.21×10^{-7}
		010-000	1595	6.27	316	22.5	1.33×10^{-5}
		001-000	3755	2.66	213	84.3	8.95×10^{-6}
		011-000	5331	1.88	24.5	19.4	1.03×10^{-6}
N_2O	0.419	001-000	2224	4.49	1858	258	7.81×10^{-5}
		010-000	589	17.0	33.2	0.322	1.4×10^{-6}
		100-000	1285	7.78	235	10.9	9.88×10^{-6}
O_3	3.553	100-000	1103	9.01	3.59	0.124	1.51×10^{-7}
		010-000	705	14.2	19.6	0.272	8.24×10^{-7}
		001-000	1042	9.60	356	10.8	1.50×10^{-5}
HO_2	--	100-000	1101	9.09	--	--	--
		010-000	1389	7.2	--	--	--
		001-000	3414	2.93	--	--	--
NO_2	8.000	100-000	1320	7.57	--	--	--
		010-000	750	13.3	--	--	--
		001-000	1618	6.19	2060	150.6	8.66×10^{-5}
		101-000	--	3.4	57	13.8	2.4×10^{-6}

Table C.2-2. (Continued)

Species	Rotational Constant B	Transition	Band Origin: Wave Number, ν_o (cm^{-1})	Band Origin: Wavelength, λ_o (μm)	Band Strength, S (cm^{-2} atm^{-1})	Einstein Coefficient, A (sec^{-1})	Oscillator Strength (f-Number)
CH_4	5.241	v_1 (1-0)	2916	3.43	Inactive	--	--
		v_2 (1-0)	1534	6.51	2.03	0.13	8.53×10^{-8}
		v_3 (1-0)	3020	3.31	324	83.	1.36×10^{-5}
		v_4 (1-0)	1306	7.66	190	9.1	7.99×10^{-6}
HNO_3	9.405	v_5 (Δv=1)	879	11.38	600	13.0	2.52×10^{-5}
NH_3	9.444	v_2 (1, 0)	--	10.5	190	4.83	7.99×10^{-6}
		v_4 (1, 0)	--	6.1	150	11.3	6.31×10^{-6}
CO	1.931	1-0 2-0	2143 4260	4.6 2.35	262. 1.89	34.7 0.96	1.09×10^{-5} 8.66×10^{-8}
NO	1.705	1-0 2-0	1876 3724	5.32 2.68	120 2	12.1 0.78	5.46×10^{-6} 8.41×10^{-8}
OH	18.871	1-0 2-0	3568 6971	2.80 1.43	~34 4	12.1 5.5	5.00×10^{-6} 6.60×10^{-7}
NO^+	2.002	1-0 2-0	2344 4655	4.26 2.15	500 3	77 1.8	*3.73×10^{-6} *2.52×10^{-8}
UO	--	1-0	776	12.88	--	--	--
FeO	0.418	Δv=1	870	11.49	450	9.5	1.89×10^{-5}
AℓO	0.641	1-0	965	10.36	190	5	8.0×10^{-6}

*From a theoretical calculation, after Billingsley.

Table C.2-3. f-Numbers for some important allowed electronic transitions. (Source: Capt. Richard Harris, AFWL)

Molecule	Transition	(v', v'')	f-Number
N_2	B-A	(0,0)	2.19×10^{-3}
	C-B	(0,0)	1.89×10^{-2}
	b′-X	(15,0)	4.2×10^{-2}
	b-X	(4,0)	3.9×10^{-2}
	c-X	(0,0)	8×10^{-3}
	c′-X	(0,0)	1.4×10^{-2}
	e-X	(0,0)	8×10^{-4}
	e′-X	(0,0)	3×10^{-3}
N_2^+	B-X	(0,0)	2.47×10^{-2}
	A-X	(0,0)	1.6×10^{-3}
O_2	B-X	(14,0)	5×10^{-5}
NO	A-X	(0,0)	4.0×10^{-4}
	B-X	(4,0)	1.2×10^{-5}
	C-X	(0,0)	4.0×10^{-4}
	D-X	(0,0)	4.1×10^{-4}
	E-X	(0,0)	3.24×10^{-4}
	S-X	(0,0)	1.7×10^{-4}
	T-X	(0,0)	1.2×10^{-4}
	M-X	(0,0)	2.2×10^{-4}
	R-X	(0,0)	1.4×10^{-4}
	Y-X	(0,0)	1.2×10^{-4}
	K-X	(0,0)	2.5×10^{-4}
	Q-X	(0,0)	1.5×10^{-4}
	W-X	(0,0)	1.2×10^{-4}
	X-X	(0,1)	1.3×10^{-7}
CO	A-X	(0,0)	4.5×10^{-2}
CN	A-X	(0,0)	5.1×10^{-4}
	B-X	(0,0)	3.64×10^{-2}

Table C.2-4. Resonance fluorescence excitation relationships. (Source: R-11, App. II and additional material (L))

Following are a group of definitions and equations which are useful in calculating infrared emission rates of gases:

A. Definitions

$S\left(cm^{-2}\ atm^{-1}\right)$	Integrated bandstrength of a transition
$S_e\left(cm^{-2}\ atm^{-1}\right)$	Bandstrength of an electronic transition
f	Oscillator strength or "f-value" of a transition
$N_{col}\left(cm^{-2}\right)$	Column density of a radiating species
λ_μ (μm)	Wavelength of a transition
$A\left(sec^{-1}\right)$	Einstein spontaneous radiative transition probability
$B\left(\text{watts cm}^{-2}\ \text{ster}^{-1}\ \mu m^{-1}\right)$	Surface brightness of a radiating volume
$R_{\lambda\mu}$ or $R_{\lambda\mu e}\left(\text{watts cm}^{-2}\mu m^{-1}\right)$	Irradiance falling upon a surface from either earthshine or sunshine, respectively.
F	Fraction of molecules in an irradiated column excited per second under the influence of sunshine irradiance

B. Equations

$$S = 0.357\lambda_\mu^2 A = 2.38 \times 10^7 f$$

$$h\nu = 1.98 \times 10^{-19}\lambda_\mu^{-1} \text{ watt-sec photon}^{-1}$$

$$F = 1.87 \times 10^{-5}\lambda_\mu^3 R_{\lambda\mu e} S$$

$F \times N_{col}$ = excitation rate along a line of sight

$$B = F N_{col} h\nu/4\pi = 2.94 \times 10^{-25}\lambda_\mu^2 R_{\lambda\mu e} S N_{col}$$

in the absence of quenching

C. Unit Conversions

1 Rayleigh = 10^6 photons cm^{-2} sec^{-1}

photons cm^{-2} sec^{-1} $ster^{-1}$ $\left(1.98 \times 10^{-19}\lambda_\mu^{-1}\ (\mu m)\right)$ = watts cm^{-2} $ster^{-1}$

ergs cm^{-2} sec^{-1} $ster^{-1}\left(10^{-7}\right)$ = watts cm^{-2} $ster^{-1}$

kiloRayleighs $\left(1.58 \times 10^{-11}\lambda_\mu^{-1}\ (\mu m)\right)$ = watts cm^{-2} $ster^{-1}$

Table C.2-5. Fluorescence efficiencies measured in auroras. (Source: R-9, Table 6)

Wavelength A	Transition	Fluorescence Efficiency	Comments
3914	$N_2^+(0,0)\ B^2\Sigma - X^2\Sigma$ 1st neg.	4.1×10^{-3}	Rocket photometer and electron energy detector
		7×10^{-3}	Satellite photometer and particle detector
4278	$N_2^+(0,0)\ B^2\Sigma - X^2\Sigma$ 1st neg.	$(11\pm4)\times10^{-4}$	Ground photometer, rocket electron detector
Laboratory derived values used extensively in ratio measurements			
3914	$N_2^+(0,0)\ B^2\Sigma - X^2\Sigma$ 1st neg.	3.7×10^{-3}	Laboratory value
4278		1.0×10^{-3}	From 3914 value and branching ratio
4709		2.2×10^{-4}	
1180	$N_2(0,13)\ h^1\Sigma - X^1\Sigma$ W-K	3×10^{-5}	Ratio with 3914
1200	N I $^4P - ^4S$	4×10^{-3}	Ratio with 3914
		7×10^{-4}	Ratio with 3914
1216	H Lyman α	5×10^{-2}	Satellite photometer, estimate of proton flux
1240	N_2 BH(5,11)	7×10^{-5}	Ratio with 3914
	N_2 BH or N I	6×10^{-4}	Ratio with 3914
1273	N_2 LBH(6,0) $a^1\Pi - X^1\Sigma$	1.1×10^{-4}	Ratio with 3914
1325	N_2 LBH(4,0)	2.6×10^{-4}	Ratio with 3914
1339	N_2 LBH(5,1)	6×10^{-5}	Ratio with 3914
1354	N_2 LBH(3,0)	5×10^{-4}	Ratio with 3914
1356	O I $^5S - ^3P$	3×10^{-4}	Ratio with 3914
		3×10^{-3}	Ratio with 3914
1382	N_2 LBH(5,2)	7.5×10^{-5}	Ratio with 3914
1384	N_2 LBH(2,0)	4×10^{-4}	Ratio with 3914
		1×10^{-4}	Ratio with 3914
1412	N_2 LBH(4,2)	2×10^{-4}	Ratio with 3914
1416	N_2 LBH(1,0)	2×10^{-4}	Ratio with 3914
1426	N_2 LBH(5,3)	7×10^{-5}	Ratio with 3914
1430	N_2 LBH(2,1)	3×10^{-4}	Ratio with 3914
1444	N_2 LBH(3,2)	2×10^{-4}	Ratio with 3914
1464	N_2 LBH(1,1)	3×10^{-4}	Ratio with 3914
		8×10^{-4}	Ratio with 3914
1473	N_2 LBH(5,4)	8×10^{-5}	Ratio with 3914
1493	N_2 LBH(3,3)	1×10^{-4}	Ratio with 3914
1493	N I $^2P - ^2D$	3×10^{-4}	Ratio with 3914
		1×10^{-3}	Ratio with 3914 (>110km)

Table C.2-5. (Continued)

Wavelength A	Transition	Fluorescence Efficiency	Comments
1508	N_2 LBH(4,4)	4×10^{-5}	Ratio with 3914
1515	N_2 LBH(1,2)	8×10^{-5}	Ratio with 3914
1530	N_2 LBH(2,3)	1×10^{-4}	Ratio with 3914
		5×10^{-4}	Ratio with 3914
1555	N_2 LBH(0,2)	5×10^{-4}	Ratio with 3914
Total N_2 BH system		6×10^{-3}	Ratio with 3914 and BH(5,11)
1205-2602 Total N_2 LBH system ($a^1\Pi$-$X^1\Sigma$)		2×10^{-2} (> 110 km)	Ratio with 3914
		3×10^{-2} (> 130 km)	Ratio with 3914
		7×10^{-3}	Ratio with 3914
2333-5060	N_2 Vegard-Kaplan bands $A^3\Sigma$-$X^1\Sigma$	7×10^{-3}	Ratio with N_2^+ (first neg.)
	(v^1 = 0) N_2 Vegard-Kaplan	1.0×10^{-3}	Ratio with 4278, from 100 km upward
	(v^1 = 1) N_2 Vegard-Kaplan	7×10^{-4}	Ratio with 4278, from 100 km upward
2470	OII ^2P-^4S	8×10^{-5}	Branching ratio with 7319-30
2972	OI ^1S-^3P	2.2×10^{-4}	Branching ratio with 5577
3371	N_2(0, 0) (2nd pos.)	2.5×10^{-3}	Ratio with 4278
3466	NI ^2P-^4S	8×10^{-5}	Ratio with 6300 OI
3727	OII ^2D-^4S	2×10^{-5}	Ratio with N_2^+ (1st neg.)
4059	N_2 2nd pos. C $^3\Pi$-B $^3\Pi$	1.6×10^{-4}	Ratio with 3914
3116-4574	Total N_2 2nd pos.	5×10^{-3}	Ratio with 3914
		3.5×10^{-3}	Ratio with N_2^+ (1st neg.)
4368	OI ^3P-^3S	1.6×10^{-5}	Ratio with 4278 N_2^+
4415	OII ^2D-^2P	1.6×10^{-5}	Ratio with 4368
4861	H_β	9×10^{-5}	Protons in post breakup display
		3.0×10^{-4}	Ratio with 3914
		2.4×10^{-4}	Ratio with 4709
		3.3×10^{-4}	Proton component in aurora

Table C.2-5. (Continued)

Wavelength A	Transition	Fluorescence Efficiency	Comments
5200	N I ^2D-^4S	3.3×10^{-5}	Ratio with 4278
		6.6×10^{-4}	Ratio with 4278 soft particles
5577	O I ^1S-^1D	4.2×10^{-3}	Ratio with 3914 (K_p = 1)
		3.1×10^{-3}	Ratio with 3914 (K_p = 4±2)
		3.9×10^{-3}	Ratio with 4278
		8.3×10^{-3}	Ratio with 3914
		$(6\pm2)\times10^{-4}$	Electrons from rockets, ground-based photometer
		2.0×10^{-3}	Ratio with 4861 in proton arc
5893	Na	2×10^{-5}	Upper limit and applicable only to low-lying displays such as type B auroras
6300	O I ^1D-^3P	8×10^{-4}	Ratio with 4278
		4×10^{-4}	Ratio with 3914
		7×10^{-3}	Ratio with 4278 soft particles
		5.6×10^{-4}	Ratio with 4861 in proton arc
6364	O I ^1D-^3P	1.2×10^{-4}	Branching ratio with 6300
6563	H_α	4.5×10^{-3}	Proton and H_α in proton arc
7319-30	O II ^2P-^2D	1.5×10^{-4}	Ratio with 5577
7036-15, 748	N_2^+ Meinel bands $A^2\Pi$-$X^2\Sigma$	3×10^{-2}	Ratio with N_2^+ (1st neg.)
7684-8598	O_2 atmospheric bands $b^1\Sigma$-$X^3\Sigma$	5×10^{-3}	Ratio with N_2^+ (1st neg.)
	O_2 (1, 1) atmospheric	3×10^{-4}	Ratio with 5577 (17)
	O_2 infrared atmospheric $a^1\Delta$-$X^3\Sigma$	8×10^{-4}	Ratio with N_2^+ (1st neg.)
5296-6419	O_2^+ (1st neg.) bands $b\,^4\Sigma$ - $a\,^4\Pi$	2×10^{-4}	Ratio with N_2^+ (1st neg.)
7774	O I ^5P-^5S	2.5×10^{-4}	Ratio with 5577
8446	O I ^3P-^3S	3.7×10^{-4}	Ratio with 5577
10400	N I ^2P-^2D	2×10^{-3}	Ratio with 5577

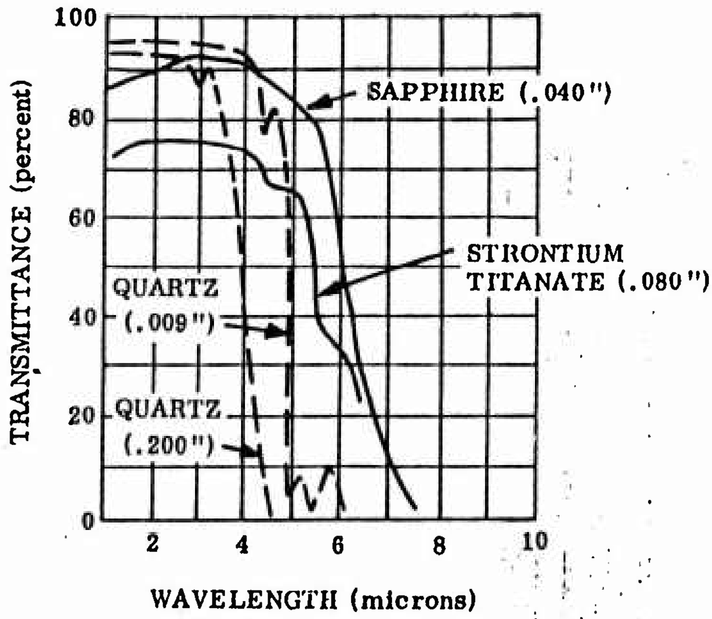


Figure C.2-8. Transmittance of optical materials used in infrared detection systems. (Source: S)

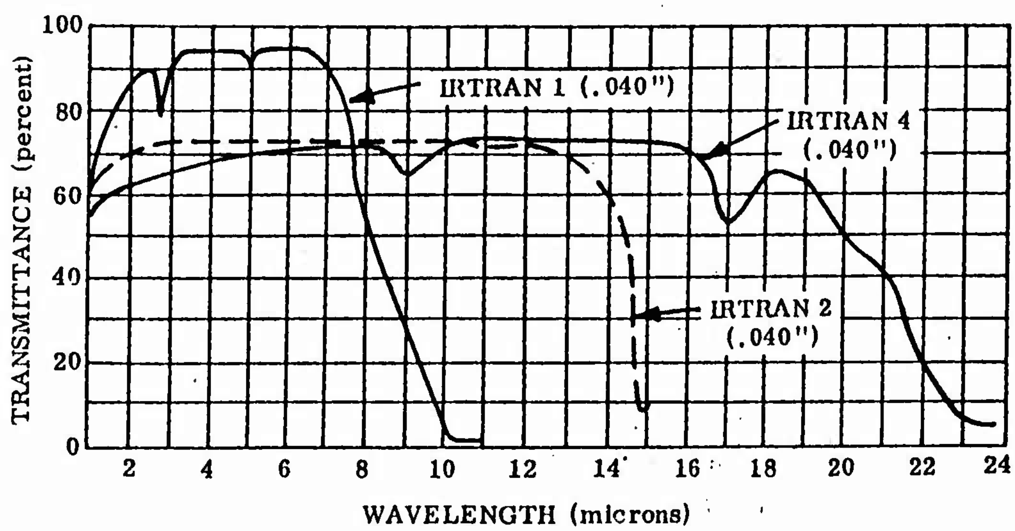


Figure C.2-9. Transmittance of optical materials used used in infrared detection systems. (Source: S)

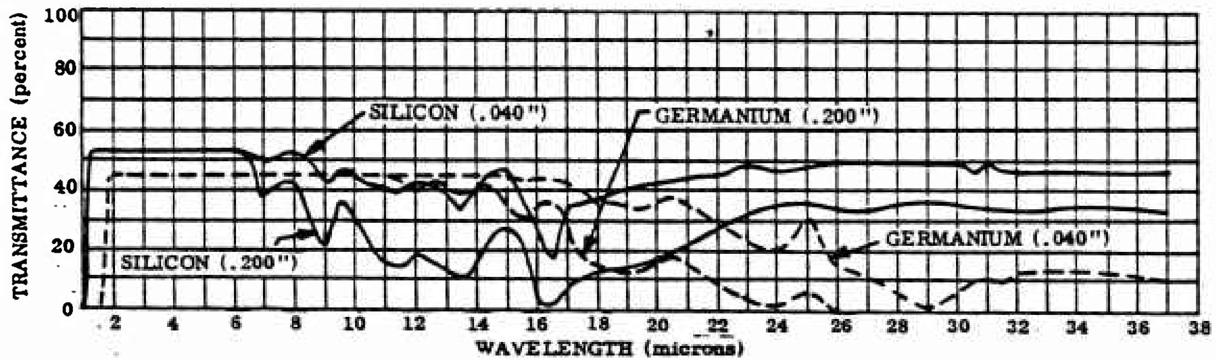


Figure C.2-10. Transmittance of optical materials used in infrared detection systems. (Source: S)

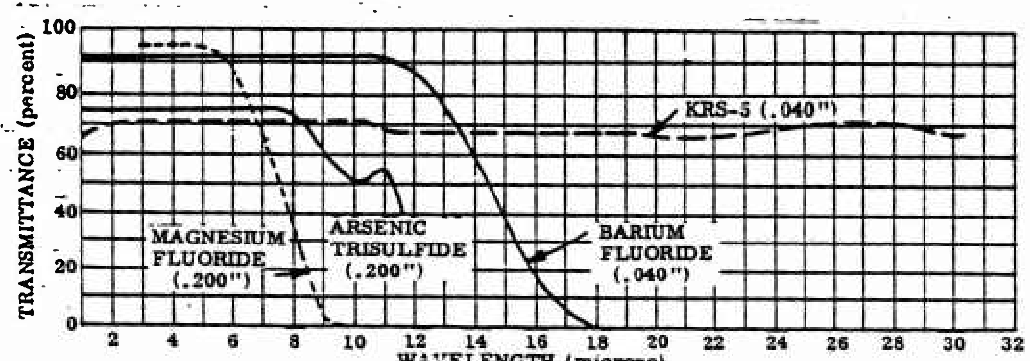


Figure C.2-11. Transmittance of optical materials used in infrared detection systems. (Source: S)

SECTION D

ELECTROMAGNETIC PROPAGATION DATA

D

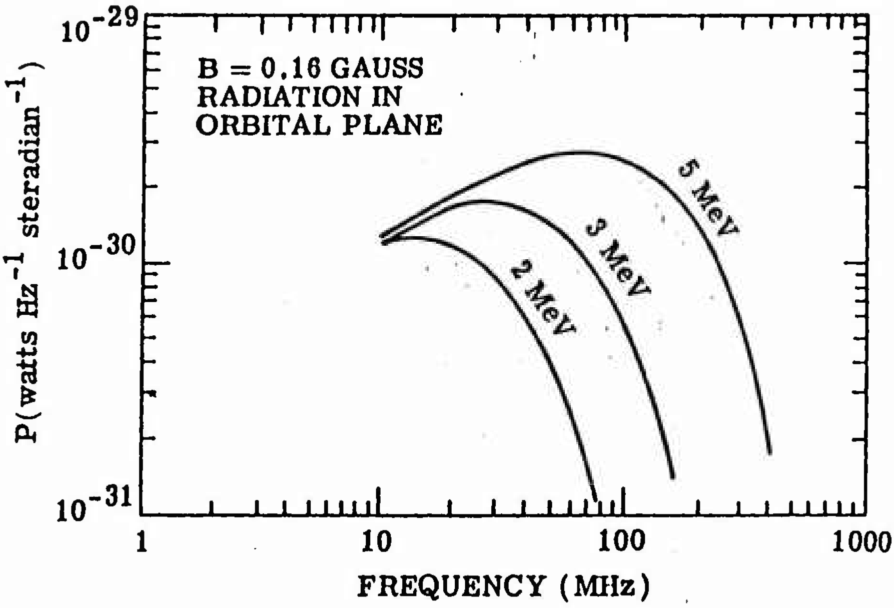


Figure D.1-1. Power per electron versus frequency with electron energy as a parameter. (Source: E-7, Figure 3)

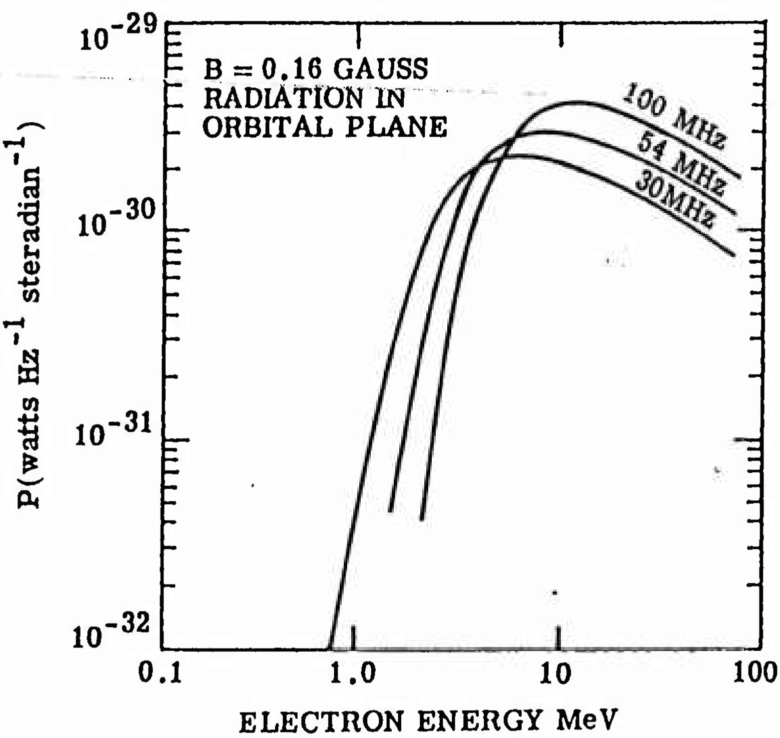


Figure D.1-2. Power per electron versus electron energy with frequency as a parameter. (Source: E-7, Figure 4)

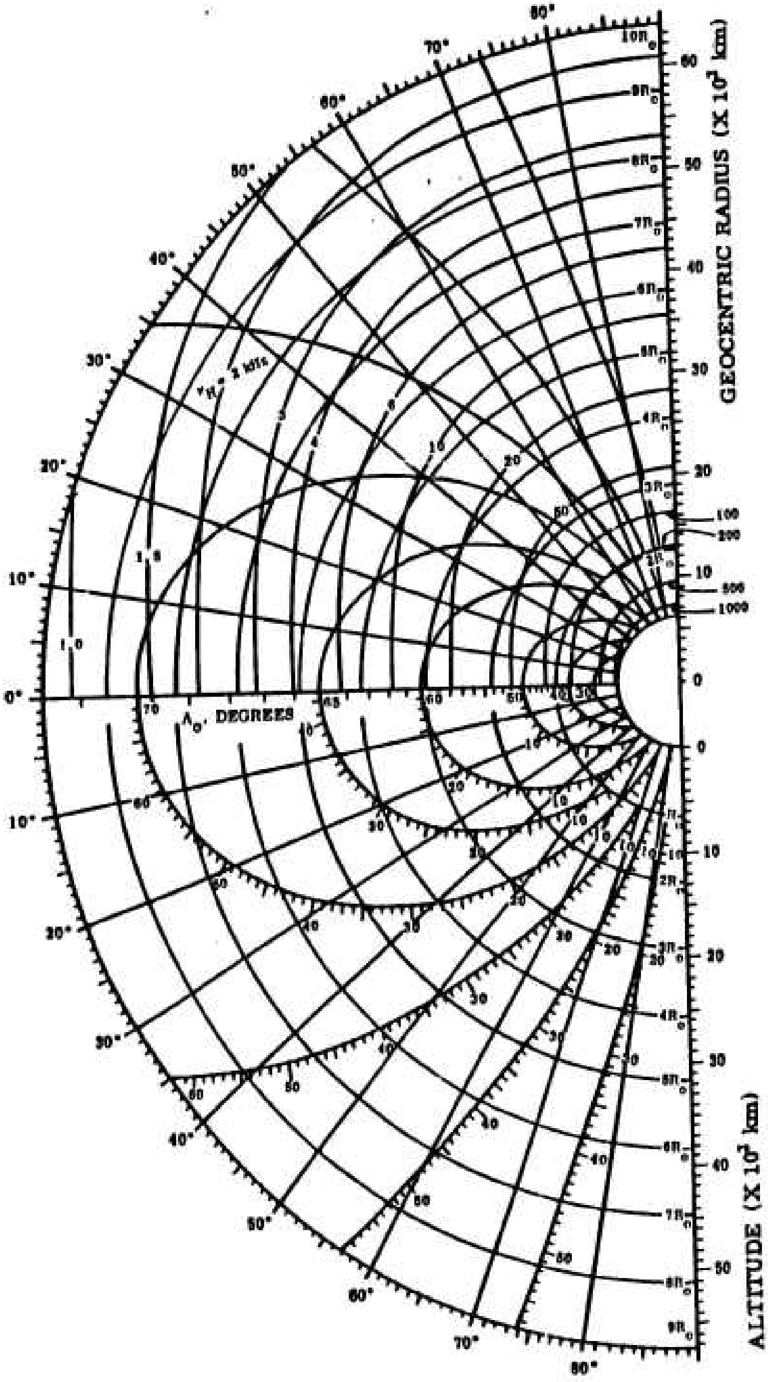


Figure D.1-3. Dipole magnetic field.
(Source: E-8, Figure 13)

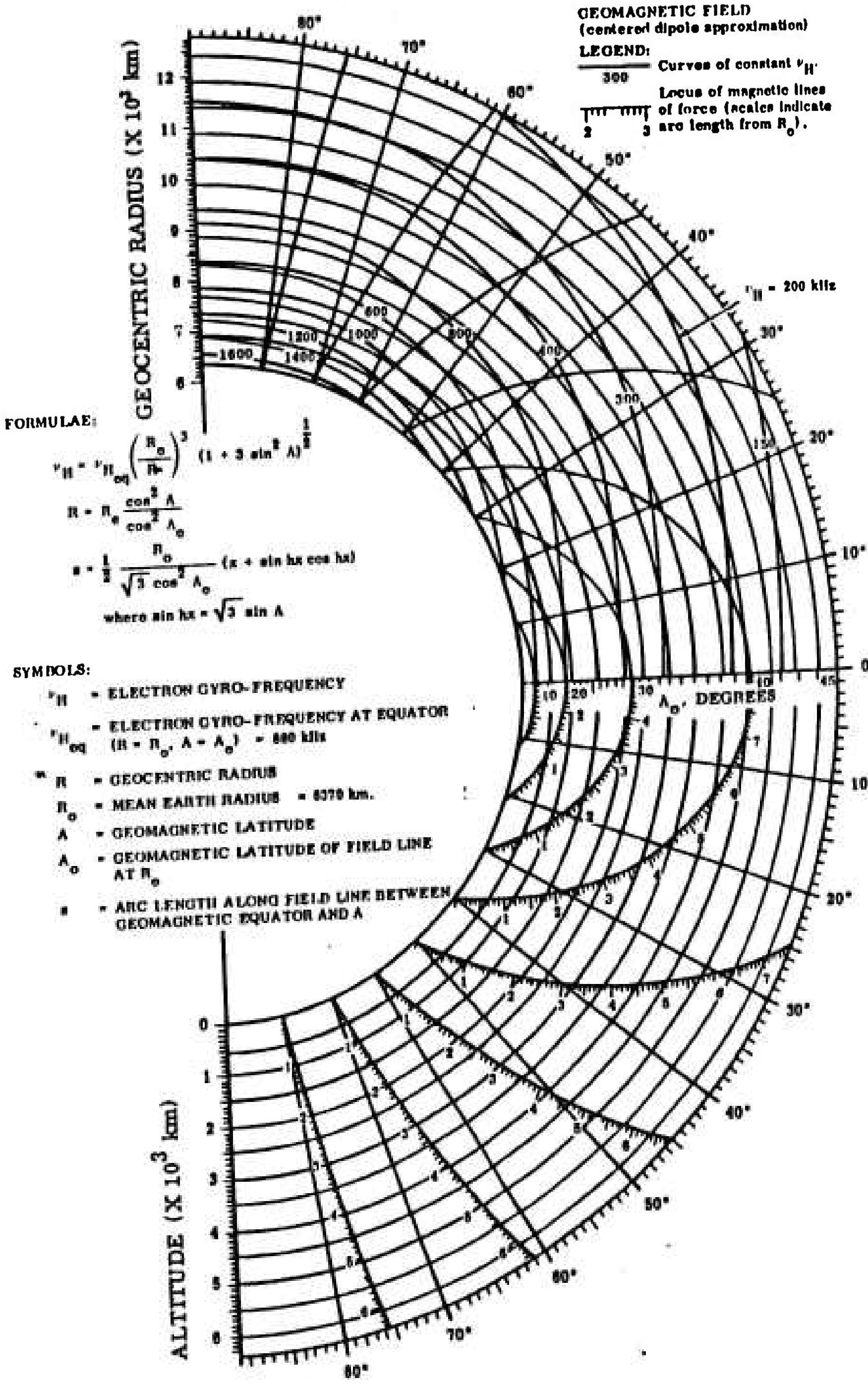


Figure D.1-3. (Continued)

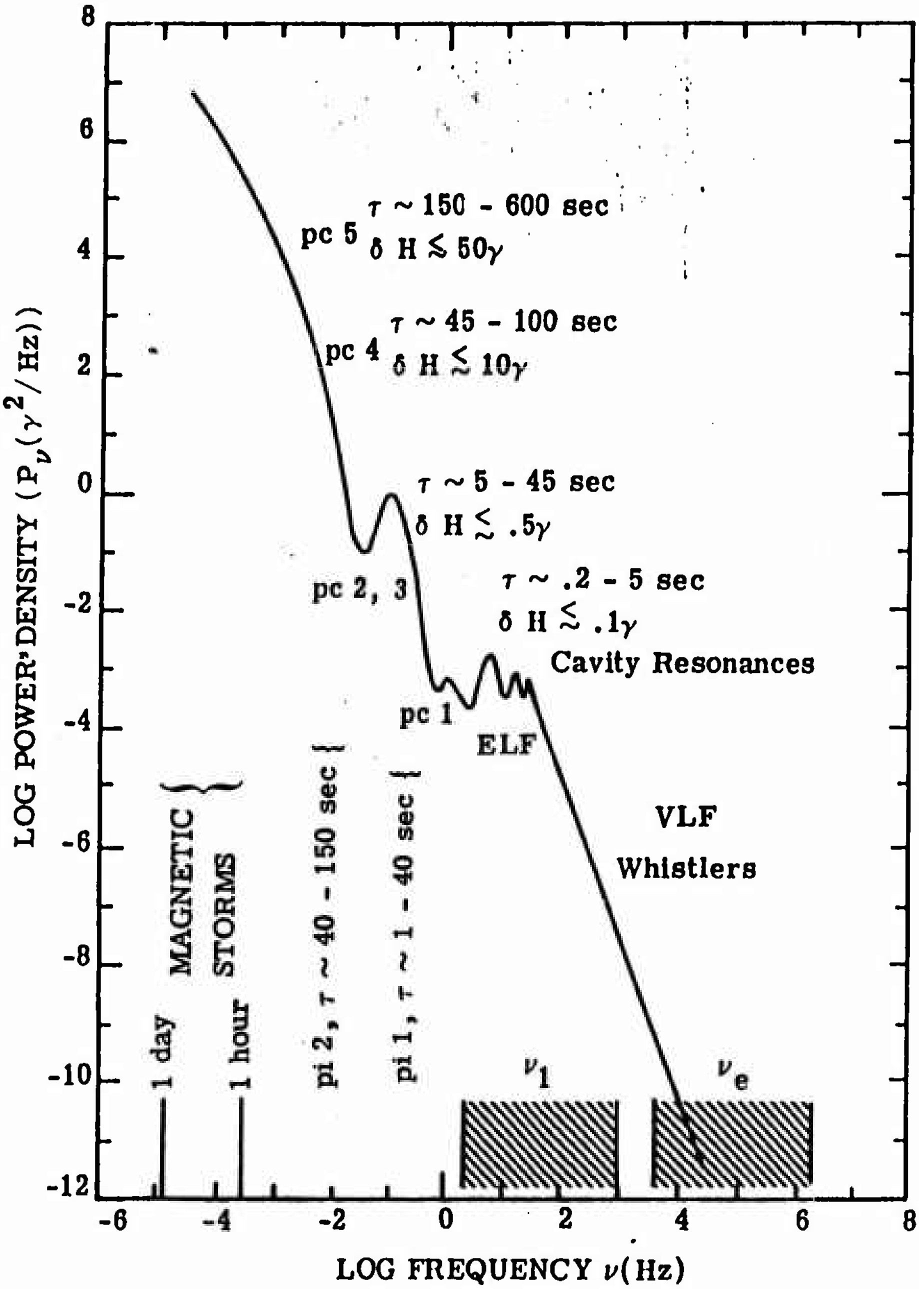


Figure D.1-4. Power spectrum of geomagnetic disturbances observed on the earth's surface. (Source: T-2, Figure 17)

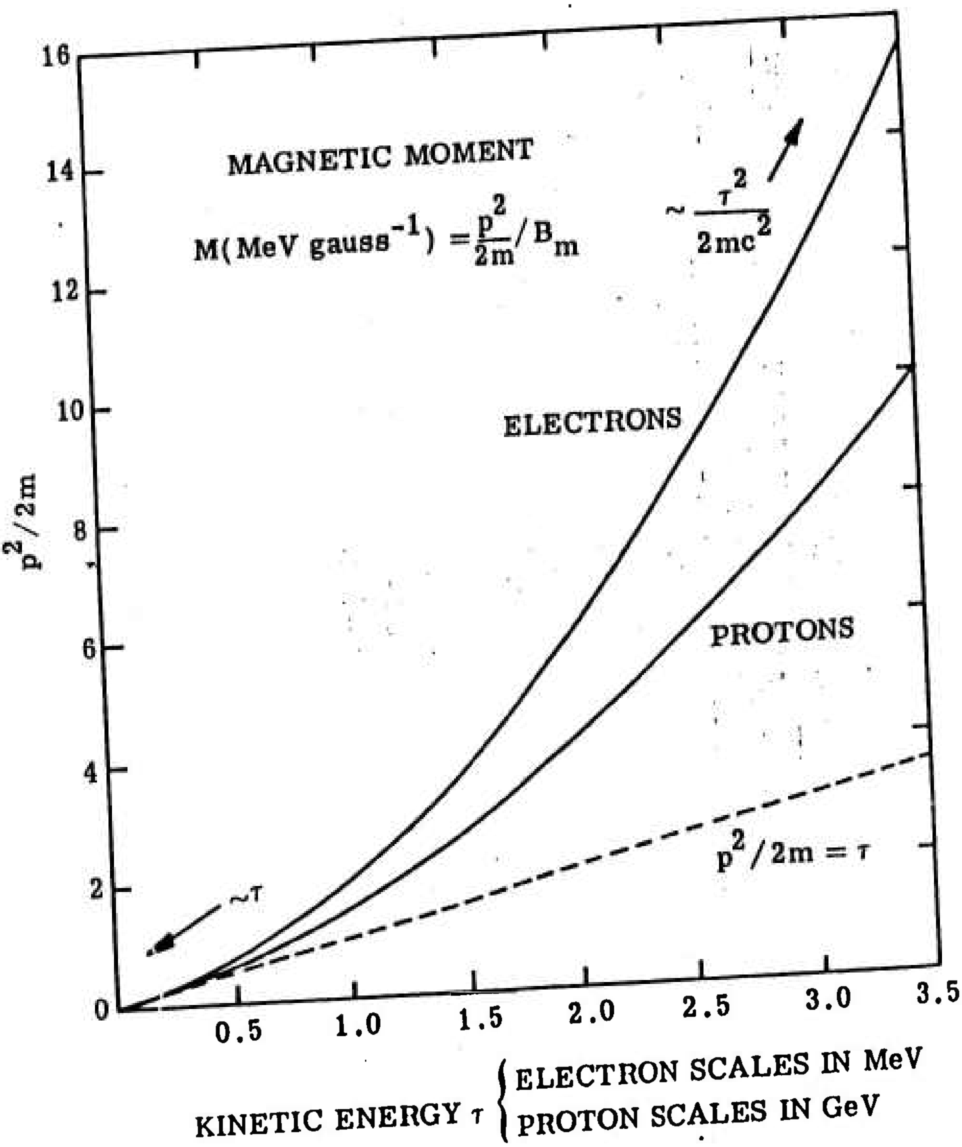


Figure D.1-5. Magnetic moment of a charged particle as a function of kinetic energy. (Source: T-3B, Figure 8)

Table D.1-1. Radar bands.

ORIGINAL RADAR BANDS	
BAND	FREQUENCY, MHz
I	100-150
G	150-225
P	225-390
L	390-1550
S	1500-5200
C	3900-6200
X	5200-10900
K	10900-36000
Q	36000-46000
V	46000-56000

CHANNEL DESIGNATIONS Since 31 December 1969		
BAND		CHANNEL WIDTH, MHz
LETTER	FREQUENCY, MHz	
A	0-250	25
B	250-500	25
C	500-1000	50
D	1000-2000	100
E	2000-3000	100
F	3000-4000	100
G	4000-6000	200
H	6000-8000	200
I	8000-10,000	200
J	10,000-20,000	1000
K	20,000-40,000	2000
L	40,000-60,000	2000
M	60,000-100,000	4000

Frequency Bands	
Band	Frequency
VLF	to 30 kHz
LF	30-300 kHz
MF	0.3-3 MHz
HF	3-30 MHz
VHF	30-300 MHz
UHF	0.3-3 GHz
SHF	3-30 GHz
EHF	30-300 GHz

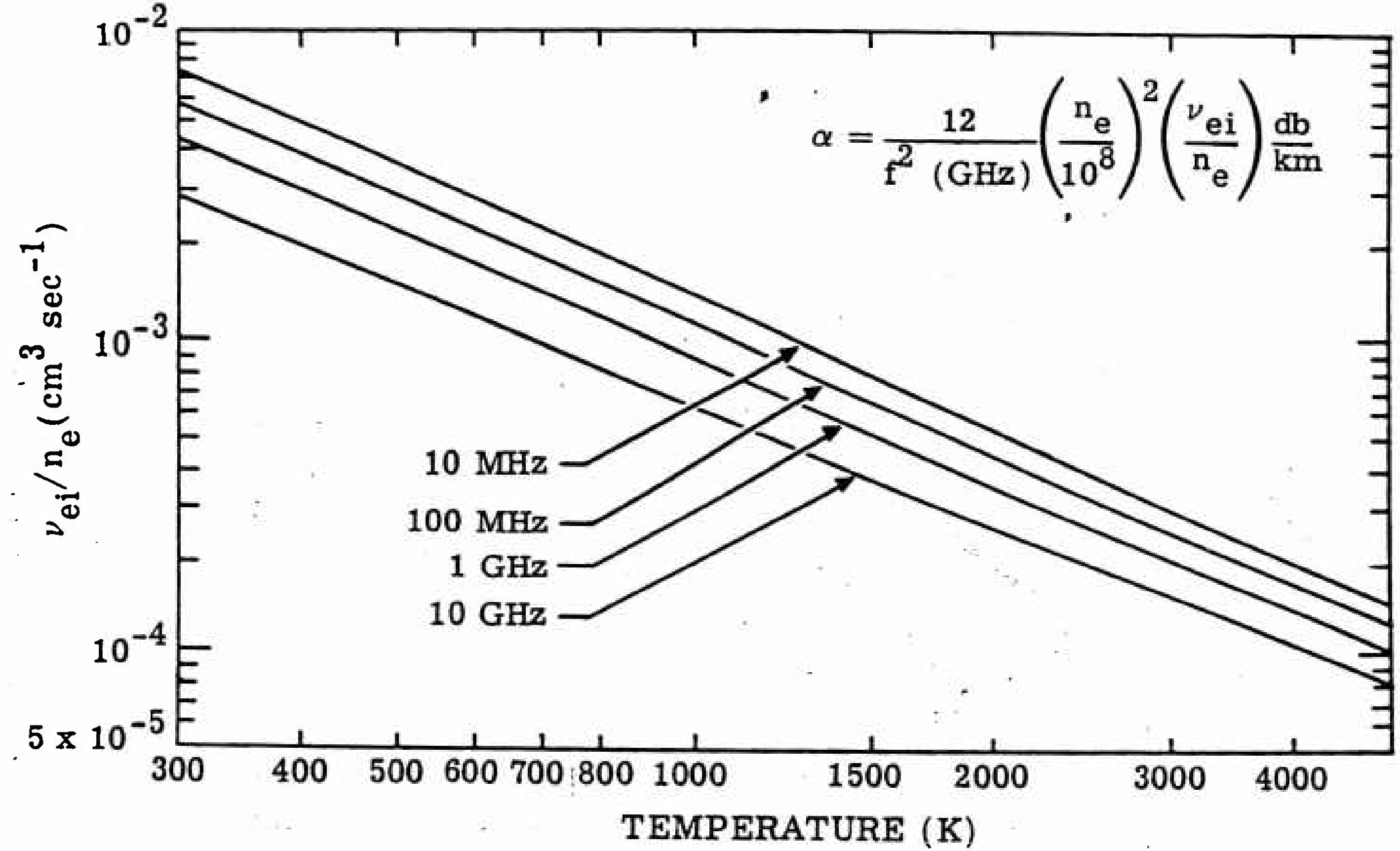


Figure D.2-1. Electron-ion collision frequency and incremental absorption. (Source: E-5, Figure 2)

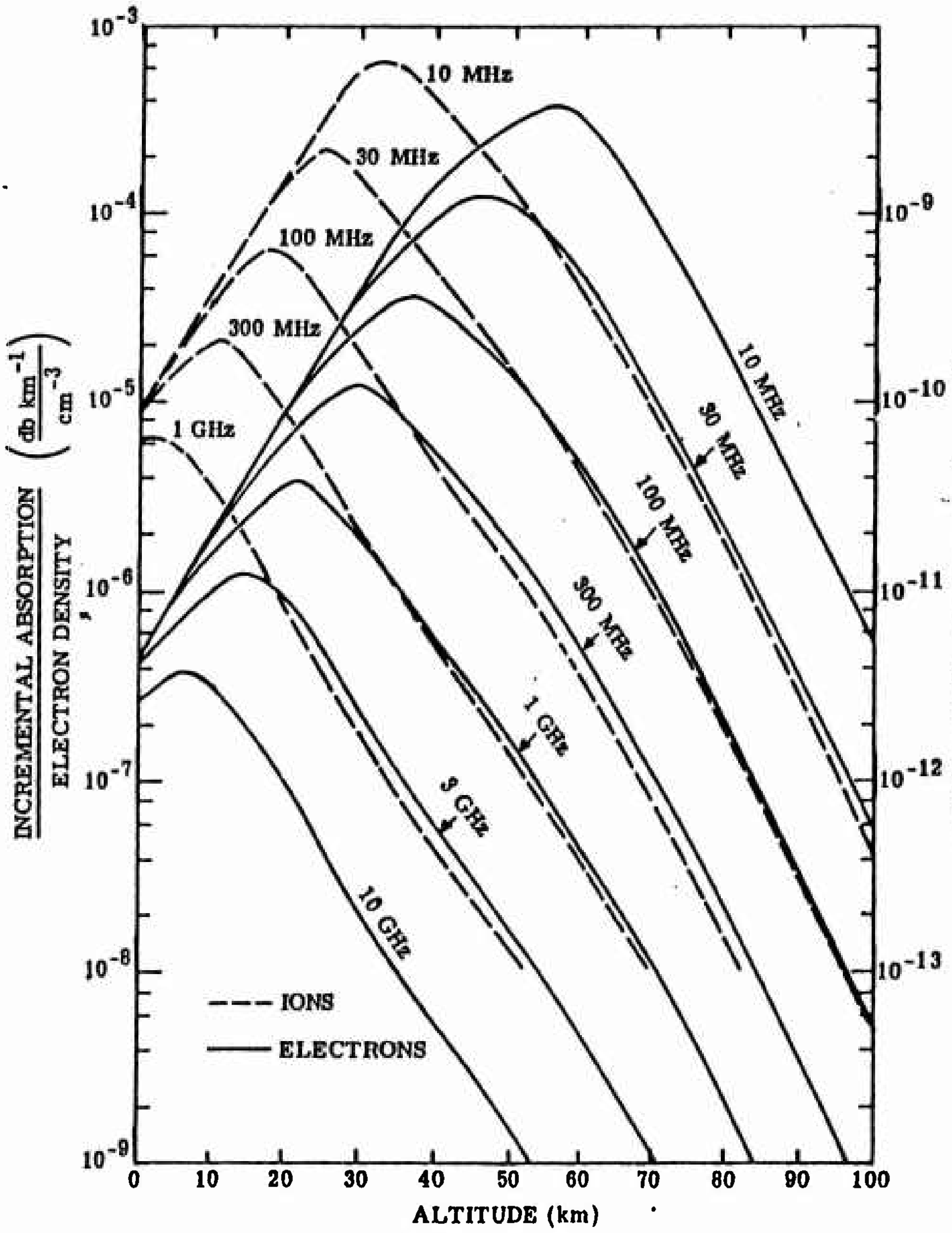


Figure D.2-2. Incremental absorption caused by electron-neutral and ion-neutral collisions (ambient atmosphere). (Source: E-5, Figure 3)

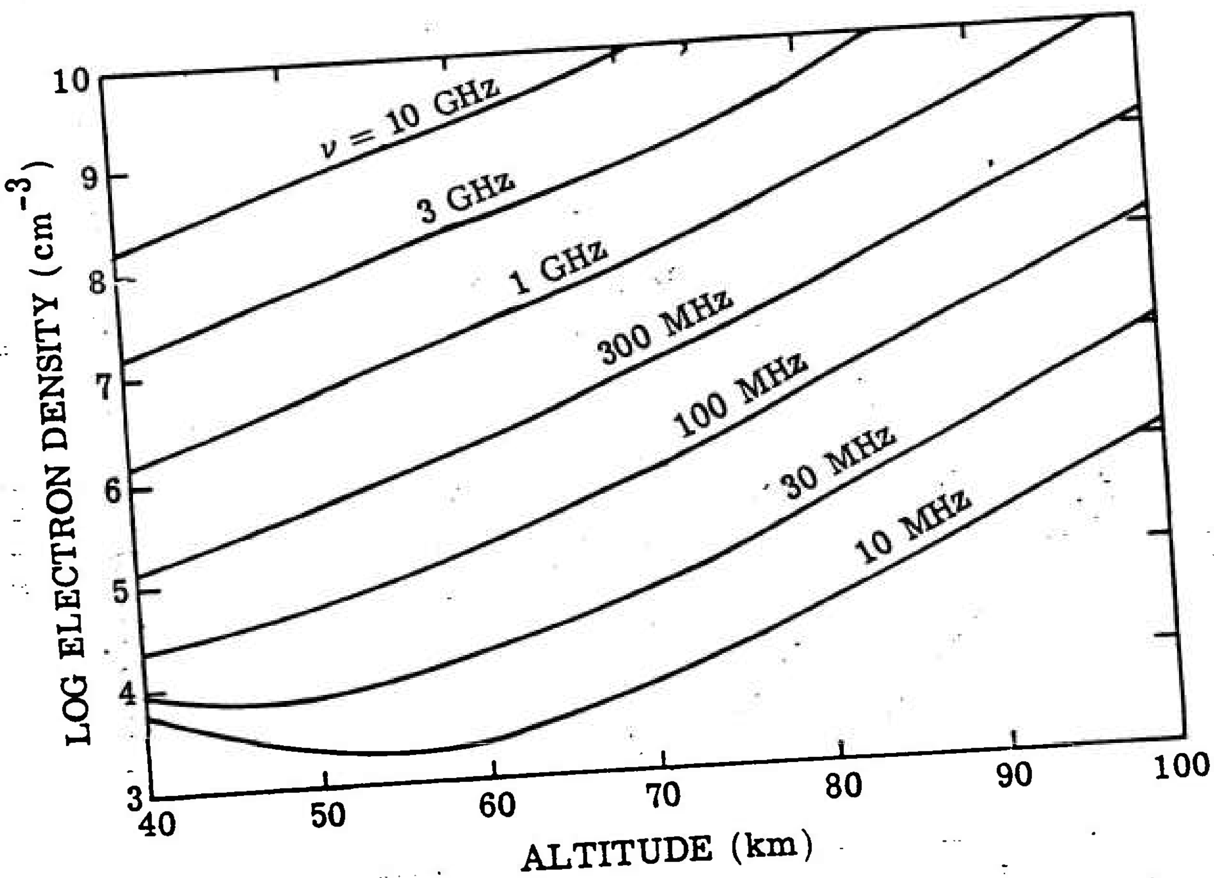


Figure D.2-3. Electron density required to produce 1-db/km incremental absorption.
(Source: E-5, Figure 4)

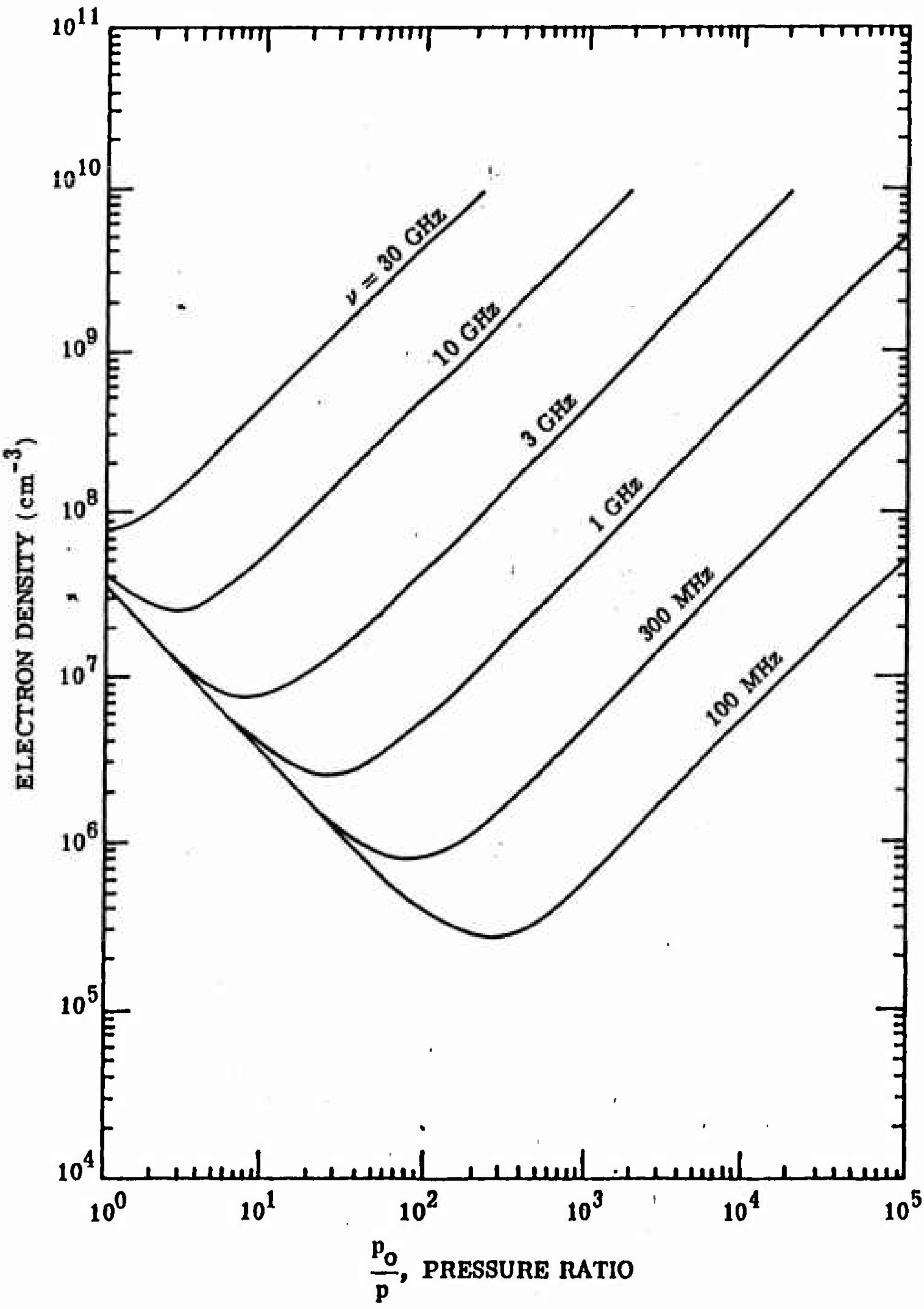


Figure D.2-4. Electron density required to produce 10 db/km incremental absorption. (Source: E-5, Figure 6)

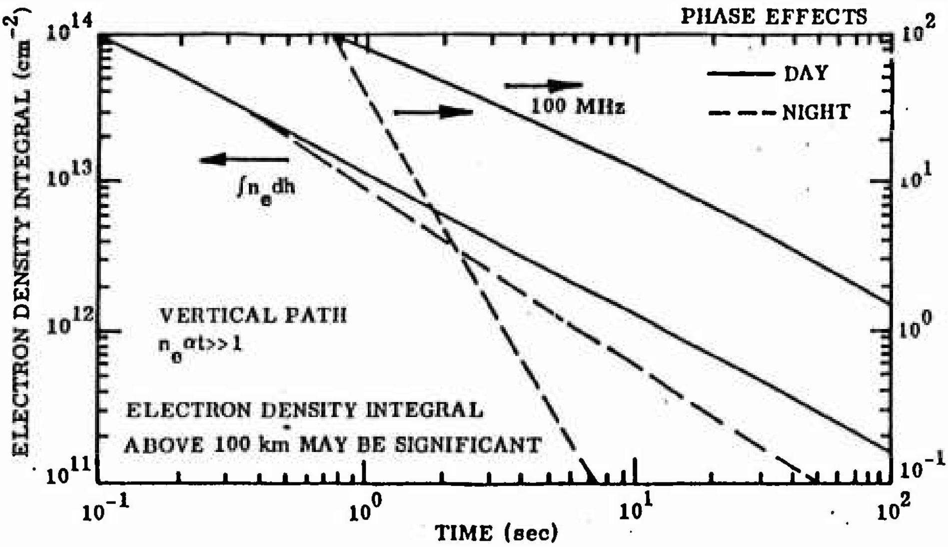


Figure D. 2-5. Integral of electron density and absorption up to 100 km altitude following an ionization impulse. (Source: E-6, Figure 1)

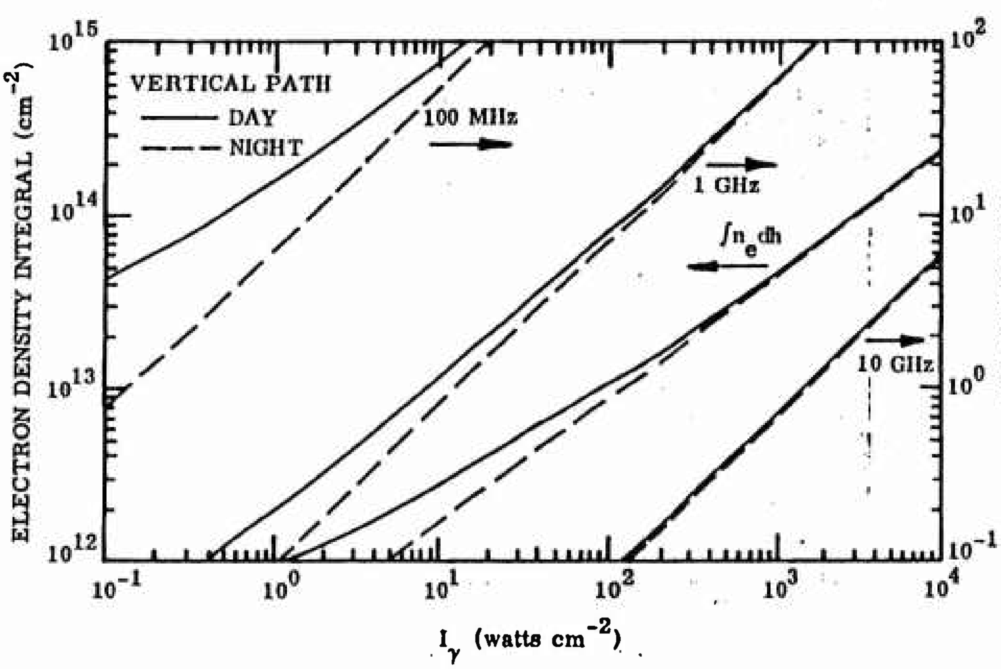


Figure D. 2-6. Integral of electron density and absorption due to delayed gamma rays. (Source: E-6, Figure 2)

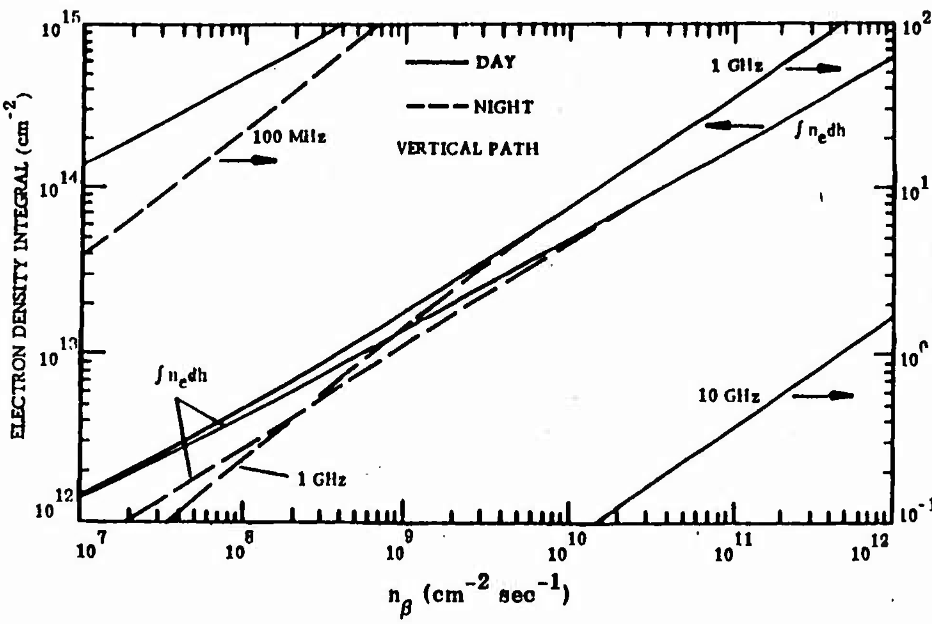


Figure D.2-7. Integral of electron density and absorption due to beta particles. (Source: E-6, Figure 3)

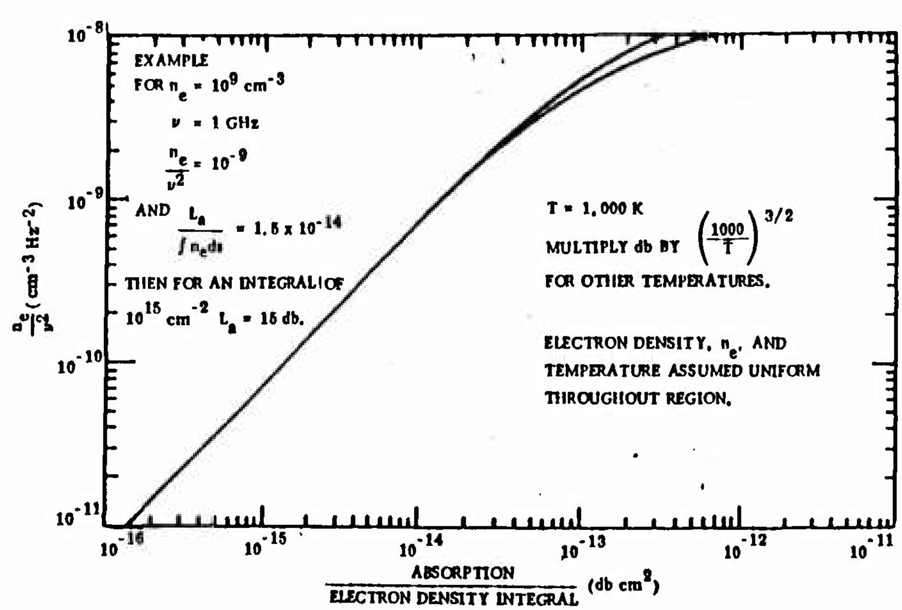


Figure D.2-8. Integral of electron density and absorption in high-altitude plasma. (Source: E-6, Figure 4)

SECTION E

CONSTANTS AND CONVERSION FACTORS

Table E.1-1. Constants. (Sources: R-App. B; E-9; T-14)

Atomic mass unit	1.660×10^{-24} g
Avogadro number	6.0225×10^{23} molecules mole^{-1}
Base of natural logarithms	2.7183 (Ln X = 2.3026 Log X)
Blackbody emittance	5.669×10^{-5} ergs cm^{-2} sec^{-1} K^{-4}
Boltzmann constant	1.3805×10^{-16} erg K^{-1}
Density of air at sea level	1.293×10^{-3} g cm^{-3}
Earth: Magnetic dipole moment	8.07×10^{25} gauss cm^{3}
Earth: Magnetic field (mean surface equatorial)	0.312 gauss
Earth: Mass	5.983×10^{27} g
Earth: Radius (mean)	6.371×10^{8} cm
Electronic charge	1.6021×10^{-19} coul
	4.803×10^{-10} esu
Electronic mass	9.109×10^{-28} g
Electronic radius	2.818×10^{-13} cm
Escape velocity from Earth's gravitational field	11.19 km sec^{-1}
Fine structure constant	7.30×10^{-3}
Gas constant	1.987 cal mole^{-1} K^{-1}
	6.95×10^{-1} cm^{-1} molecule^{-1} K^{-1}
	82.05 cm^{3} atm mole^{-1} K^{-1}
	8.61×10^{-5} eV molecule^{-1} K^{-1}
	8.3144×10^{7} erg mole^{-1} K^{-1}
	1.38×10^{-16} erg molecule^{-1} K^{-1}
	1 K^{-1}
	1.987×10^{-3} kcal mole^{-1} K^{-1}
	8.205×10^{-2} liter atm mole^{-1} K^{-1}

Table E.1-1. (Continued)

Gravitational acceleration	980.665 cm sec^{-2}
Gravitational constant	6.668×10^{-8} $cm^3 g^{-1} sec^{-2}$
Loschmidt number	2.69×10^{19} molecules cm^{-3}
Mechanical equivalent of heat	4.186 joules $(g\text{-cal})^{-1}$
Planck constant	6.6256×10^{-27} erg sec
Proton mass	1.6724×10^{-24} g
Rydberg constant	1.097×10^{5} cm^{-1}
Solar constant (total radiation flux received on Earth)	1.388×10^{6} erg cm^{-2} sec^{-1}
Sunspot cycle period (mean)	11.04 yr
Velocity of light in vacuum	2.99793×10^{10} cm sec^{-1}
Velocity of sound in air at STP	331.7 m sec^{-1}

ORDERS OF MAGNITUDE

Order	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Table E.2-1. Conversion factors.
(Source: R-App. C)

ALTITUDE

	km	kft	statute miles	nautical miles
1 kilometer	1	3.281	0.6214	0.5396
1 kilofoot	0.3048	1	0.1894	0.1645
1 statute mile	1.609	5.280	1	0.8690
1 nautical mile	1.853	6.080	1.1516	1

ANGLE

	minutes	degrees	radians	revolutions
1 second	1.667×10^{-2}	2.778×10^{-4}	4.848×10^{-6}	7.72×10^{-8}
1 minute	1	1.667×10^{-2}	2.909×10^{-4}	4.63×10^{-6}
1 degree	60	1	1.745×10^{-2}	2.7×10^{-3}
1 radian	3.44×10^{3}	57.30	1	0.1592
1 revolution	2.16×10^{5}	360	6.283	1

Table E.2-1. (Continued)

CONCENTRATION

	atm	moles liter^{-1}	molecules cm^{-3}	ppm	torr
1 atmosphere	1	$0.122\ T^{-1}$	$7.34 \times 10^{21}\ T^{-1}$	1×10^{6}	760
1 mole liter^{-1}	$8.21\ T$	1	6.02×10^{20}	$8.21 \times 10^{6}\ T$	$6.24 \times 10^{3}\ T$
1 molecule cm^{-3}	$1.36 \times 10^{-22}\ T$	1.66×10^{-21}	1	$1.36 \times 10^{-16}\ T$	$1.04 \times 10^{-19}\ T$
1 ppm	1×10^{-6}	$1.22 \times 10^{-7}\ T^{-1}$	$7.33 \times 10^{15}\ T^{-1}$	1	7.6×10^{-4}
1 torr	1.32×10^{-3}	$1.61 \times 10^{-4}\ T^{-1}$	$9.64 \times 10^{18}\ T^{-1}$	1.32×10^{3}	1

1 atmosphere (0 C) $= 2.69 \times 10^{19}$ molecules cm^{-3}
(25 C) $= 2.45 \times 10^{19}$ molecules cm^{-3}

1 ppm (0 C) $= 2.69 \times 10^{13}$ molecules cm^{-3}
(25 C) $= 2.45 \times 10^{13}$ molecules cm^{-3}

1 torr (0 C) $= 3.53 \times 10^{16}$ molecules cm^{-3}
(25 C) $= 3.24 \times 10^{16}$ molecules cm^{-3}

CROSS-SECTION

$1\ cm^2 = 10^{24}$ barns $= 10^{18}$ megabarns

$a_o^2 = 2.80 \times 10^{-17}\ cm^2$

$1\ cm^2 = 3.54 \times 10^{16}\ cm^{-1}$ (at 1 torr, 0 C)

$\pi a_o^2 = 8.80 \times 10^{-17}\ cm^2$

Table E.2-1. (Continued)

CONCENTRATION AND PRESSURE NOMOGRAPH AND CONVERSION CHART

N.B.: The sample calculation may be read as follows:
A number density of 2×10^{13} cm^{-3}, equivalent to 3.33×10^{-8} moles/liter when projected through a temperature of 300K, is, equal to a pressure of 8.2×10^{-7} atm, or 6.23×10^{-4} torr.

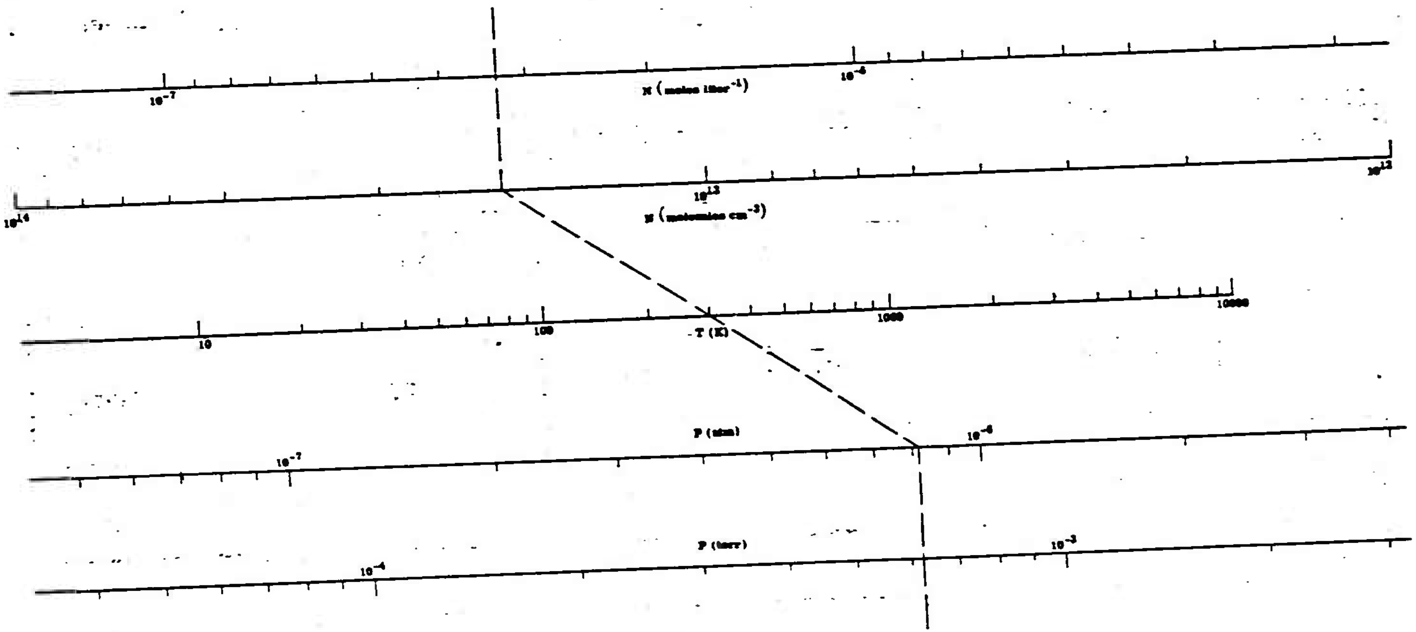


Table E.2-1. (Continued)

ENERGY

	eV [a]	ergs [a]	cm^{-1} [a]	kcal $mole^{-1}$ [a]	Corresponding Temperature (K) [b]
1 eV	1	1.602×10^{-12}	8067.5	23.069	11,605.
1 erg	6.24×10^{11}	1	5.03×10^{15}	1.44×10^{13}	7.24×10^{15}
1 joule	6.24×10^{18}	1×10^{7}	5.03×10^{22}	1.44×10^{20}	
1 jerk	6.24×10^{27}	1×10^{16}	5.03×10^{31}	1.44×10^{29}	
1 cm^{-1} (= 1 kayser)	1.24×10^{-4}	1.99×10^{-16}	1	2.86×10^{-3}	1.44
1 kcal $mole^{-1}$	4.335×10^{-2}	6.95×10^{-14}	350.	1	503.
1 Rydberg	13.605	2.18×10^{-11}	1.098×10^{5}	314.	1.58×10^{5}
1 ton TNT	2.6×10^{28}	4.2×10^{16}	2.1×10^{32}	6.0×10^{29}	-
1 liter atm (0 C)		1.01×10^{9}			
1 watt sec		1×10^{7}			
1 Hartree	27.210				

Notes:

[a] In comparing eV, ergs, etc., with kcal $mole^{-1}$, the energy units must be regarded as being per molecule, i.e., as eV per molecule, erg per molecule, etc.

[b] This is the temperature which a gas would have if its molecules had an average translational energy per molecule of one unit, e.g., one eV, one erg, etc.

Table E.2-1. (Continued)

LENGTH (see also Altitude, Wavelength)

	cm	meters	inches	feet
1 A	10^{-8}	10^{-10}	3.937×10^{-9}	3.281×10^{-10}
1 μm	10^{-4}	10^{-6}	3.937×10^{-5}	3.281×10^{-6}
1 cm	1	10^{-2}	0.3937	3.281×10^{-2}
1 meter	100	1	39.37	3.281
1 inch	2.540	2.54×10^{-2}	1	8.33×10^{-2}
1 foot	30.48	0.3048	12.0	1
1 astronomical unit = 1.495×10^{11} miles				
1 Bohr unit = 5.2917×10^{-1} A				

MASS

	grams	ounces	pounds	tons
1 gram	1	3.53×10^{-2}	2.205×10^{-3}	1.10×10^{-6}
1 ounce	28.35	1	6.25×10^{-2}	3.12×10^{-5}
1 pound	453.6	16.0	1	5.0×10^{-4}
1 ton	9.07×10^{5}	3.2×10^{4}	2.0×10^{3}	1

Table E.2-1. (Continued)
PRESSURE CONVERSION CHART

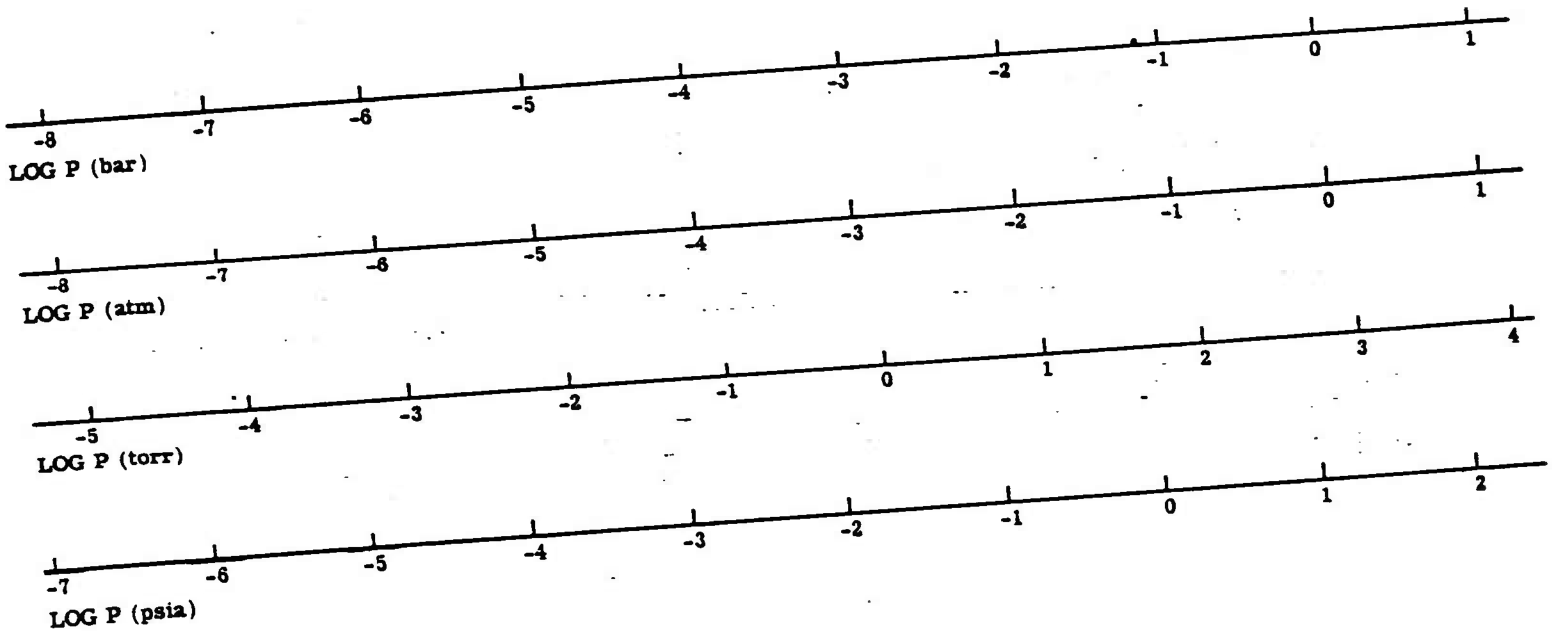


Table E.2-1. (Continued)

PRESSURE

	atm	bar	psi	torr
1 atmosphere	1	1.0133	14.70	760
1 bar	0.9869	1	14.51	750
1 dyne cm^{-2}	9.87×10^{-7}	1×10^{-6}	1.45×10^{-5}	7.50×10^{-4}
1 newton m^{-2}	9.87×10^{-6}	1×10^{-5}	1.45×10^{-4}	7.50×10^{-3}
1 inch H_2O (4° C.)	2.46×10^{-3}	2.49×10^{-3}	3.61×10^{-2}	1.868
1 psi	6.804×10^{-2}	6.91×10^{-2}	1	51.72
1 torr = 1 mm Hg	1.316×10^{-3}	1.33×10^{-3}	1.93×10^{-2}	1

REACTION-RATE CONSTANTS

Bimolecular:

$$k\ (cm^3 molecule^{-1} sec^{-1}) \times 6.02 \times 10^{20} = k\ (liter\ mole^{-1}\ sec^{-1})$$

$$k\ (liter\ mole^{-1} sec^{-1}) \times 1.66 \times 10^{-21} = k\ (cm^3 molecule^{-1} sec^{-1})$$

$$k\ (ppm^{-1} min^{-1}) \times 2.27 \times 10^{-18} T = k\ (cm^3 molecule^{-1} sec^{-1})$$

$$k\ (ppm^{-1} sec^{-1}) \times 1.36 \times 10^{-16} T = k\ (cm^3 molecule^{-1} sec^{-1})$$

$$k\ (ppm^{-1} sec^{-1}) \times 4.05 \times 10^{-14} = k\ (cm^3 molecule^{-1} sec^{-1}) \text{ at 25 C}$$

$$k\ (torr^{-1} sec^{-1}) \times 1.04 \times 10^{-19} T = k\ (cm^3 molecule^{-1} sec^{-1})$$

$$k\ (torr^{-1} sec^{-1}) \times 2.84 \times 10^{-17} = k\ (cm^3 molecule^{-1} sec^{-1}) \text{ at 0 C}$$

$$k\ (torr^{-1} sec^{-1}) \times 3.10 \times 10^{-17} = k\ (cm^3 molecule^{-1} sec^{-1}) \text{ at 25 C}$$

Table E.2-1. (Continued)

REACTION-RATE CONSTANTS (Cont'd.)

Termolecular:

$$k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1}) \times 3.62 \times 10^{41} = k\,(\text{liter}^2\,\text{mole}^{-2}\,\text{sec}^{-1})$$

$$k\,(\text{liter}^2\,\text{mole}^{-2}\,\text{sec}^{-1}) \times 2.76 \times 10^{-42} = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1})$$

$$k\,(\text{ppm}^{-2}\,\text{min}^{-1}) \times 5.15 \times 10^{-36}\,T^2 = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1})$$

$$k\,(\text{ppm}^{-2}\,\text{sec}^{-1}) \times 1.85 \times 10^{-32}\,T^2 = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1})$$

$$k\,(\text{ppm}^{-2}\,\text{sec}^{-1}) \times 1.64 \times 10^{-27} = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1}) \text{ at } 25\,\text{C}$$

$$k\,(\text{torr}^{-2}\,\text{sec}^{-1}) \times 1.08 \times 10^{-38}\,T^2 = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1})$$

$$k\,(\text{torr}^{-2}\,\text{sec}^{-1}) \times 8.05 \times 10^{-34} = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1}) \text{ at } 0\,\text{C}$$

$$k\,(\text{torr}^{-2}\,\text{sec}^{-1}) \times 9.59 \times 10^{-34} = k\,(\text{cm}^6\,\text{molecule}^{-2}\,\text{sec}^{-1}) \text{ at } 25\,\text{C}$$

TEMPERATURE

$$T\,(C) = T\,(K) - 273.16$$
$$T\,(C) = [T\,(F) - 32]/1.8$$
$$T\,(C) = [T\,(R) - 491.7]/1.8$$

$$T\,(F) = 1.8\,T\,(C) + 32$$
$$T\,(F) = 1.8\,T\,(K) - 459.7$$
$$T\,(F) = T\,(R) - 459.7$$

$$T\,(K) = T\,(C) + 273.16$$
$$T\,(K) = [T\,(F) - 32]/1.8 + 273.16$$
$$T\,(K) = [T\,(R) - 491.7]/1.8 + 273.16$$

$$T\,(R) = 1.8\,T\,(C) + 491.7$$
$$T\,(R) = T\,(F) + 459.7$$
$$T\,(R) = 1.8\,[T\,(K) - 273.16] + 491.7$$

$$1\,C = 1\,K = 1.8\,F = 1.8\,R$$

Table E.2-1. (Continued)
TEMPERATURE CONVERSION CHART

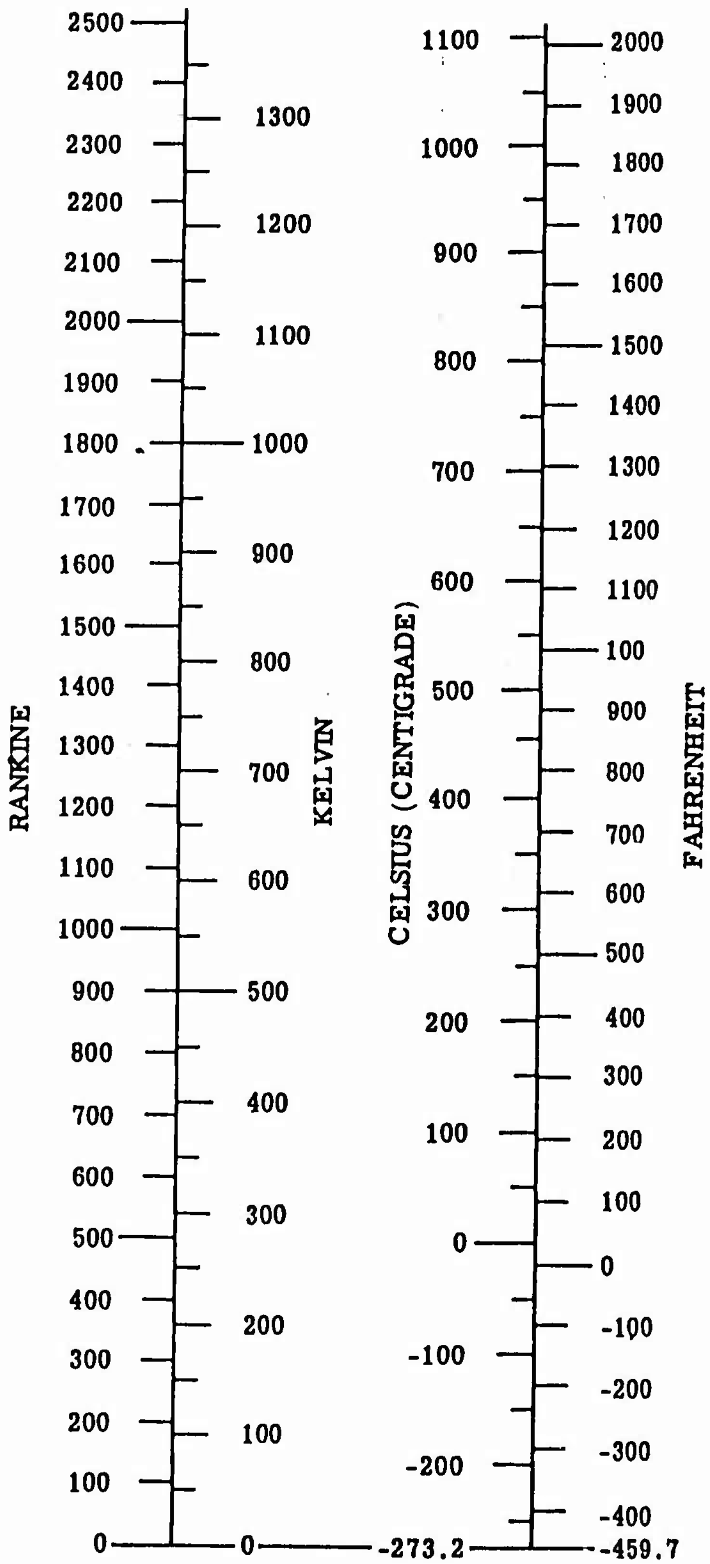


Table E.2-1. (Continued)

TIME CONVERSION CHART

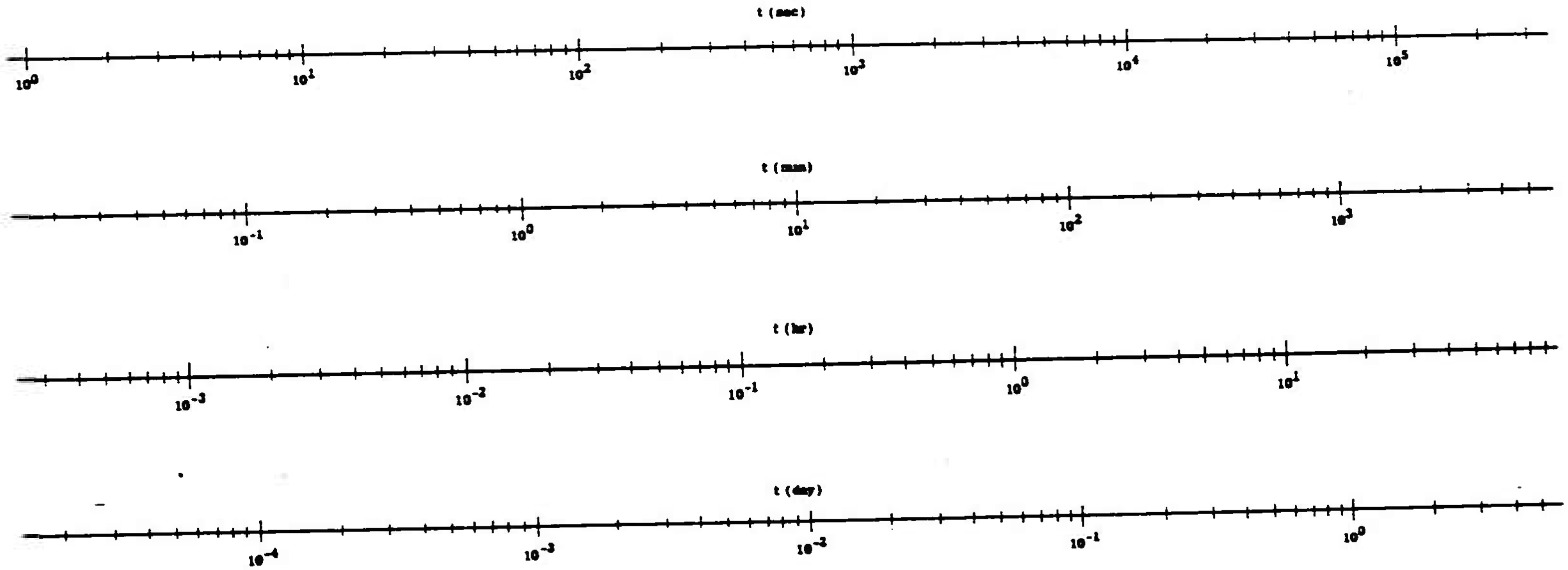


Table E.2-1. (Continued)

TIME

	secs	mins	hrs	days
1 shake	1×10^{-8}			
1 second	1	1.667×10^{-2}	2.77×10^{-4}	1.16×10^{-5}
1 minute	60	1	1.667×10^{-2}	6.94×10^{-4}
1 hour	3600	60	1	4.167×10^{-2}
1 day	8.64×10^{4}	1.44×10^{3}	24	1

VELOCITY

$1 \text{ cm sec}^{-1} = 2.237 \times 10^{-2} \text{ mi hr}^{-1}$

$1 \text{ ft sec}^{-1} = 30.48 \text{ cm sec}^{-1}$

$1 \text{ ft sec}^{-1} = 0.6818 \text{ mi hr}^{-1}$

$1 \text{ knot} = 1 \text{ nautical mi hr}^{-1}$

$1 \text{ knot} = 51.5 \text{ cm sec}^{-1}$

$1 \text{ knot} = 1.689 \text{ ft sec}^{-1}$

$1 \text{ mi hr}^{-1} = 44.70 \text{ cm sec}^{-1}$

$1 \text{ mi hr}^{-1} = 1.467 \text{ ft sec}^{-1}$

Table E.2-1. (Continued)

VOLUME

	cm^3	ft^3	in^3
1 cm^3	1	3.531×10^{-5}	6.102×10^{-2}
1 ft^3	2.832×10^4	1	1.728×10^3
1 in^3	16.39	5.787×10^{-4}	1
1 gallon	3.785×10^3	0.1337	231
1 liter	1000	3.531×10^{-2}	61.02

WAVELENGTH

	A	cm	μm	nm
1 A	1	10^{-8}	10^{-4}	10^{-1}
1 cm	10^8	1	10^4	10^7
1 μm	10^4	10^{-4}	1	10^3
1 nm	10^1	10^{-7}	10^{-3}	1

WAVELENGTH - ENERGY

$$\lambda(A) \times E\,(eV) = 12{,}400.$$

$$\lambda(A) \times E\,(erg\ photon^{-1}) = 2 \times 10^{-8}$$

Table E.2-1. (Continued)

WAVELENGTH-ENERGY CONVERSION CHART
(LOW RANGE)

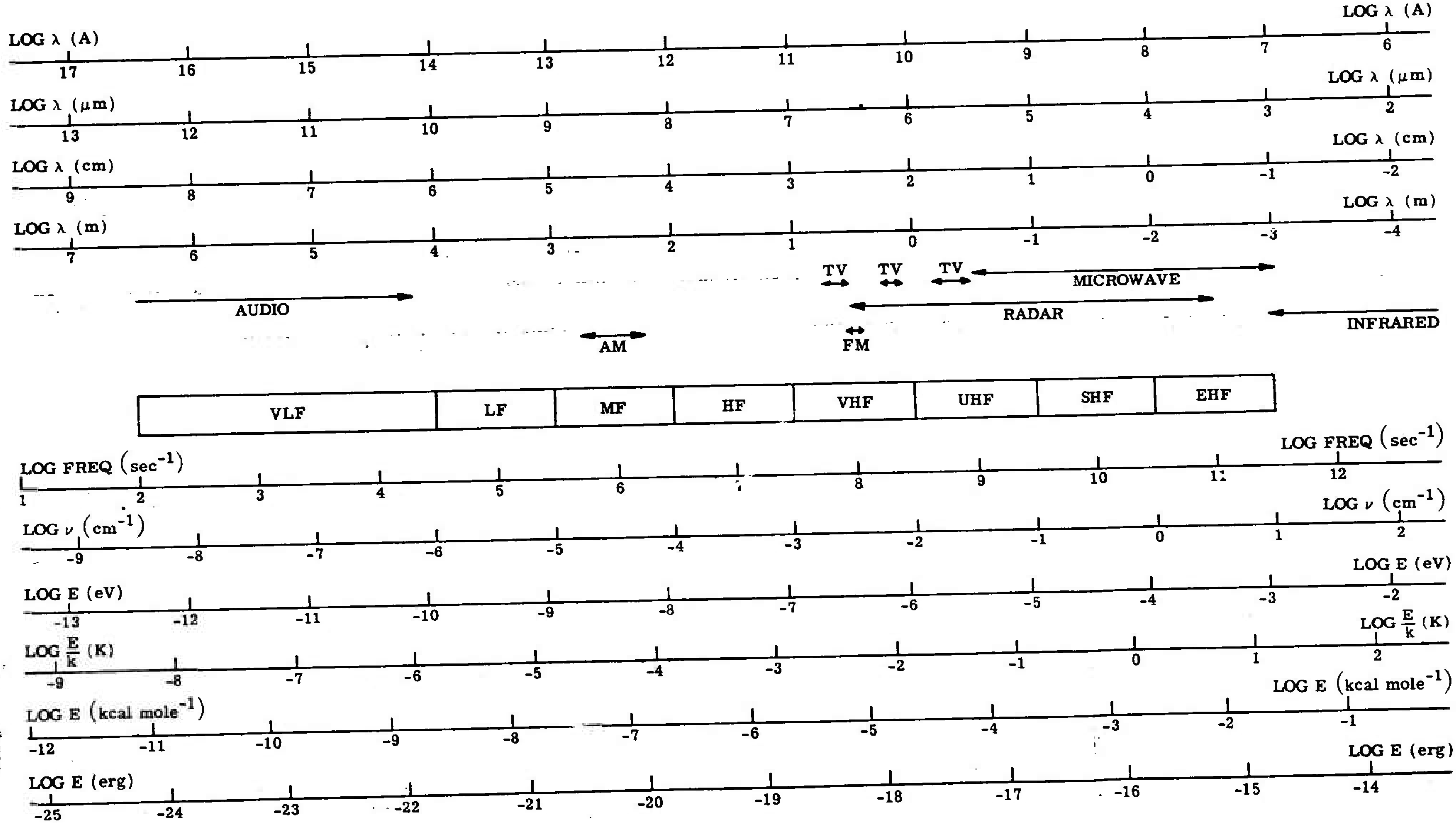


Table E.2-1. (Continued)

WAVELENGTH-ENERGY CONVERSION CHART
(HIGH RANGE)

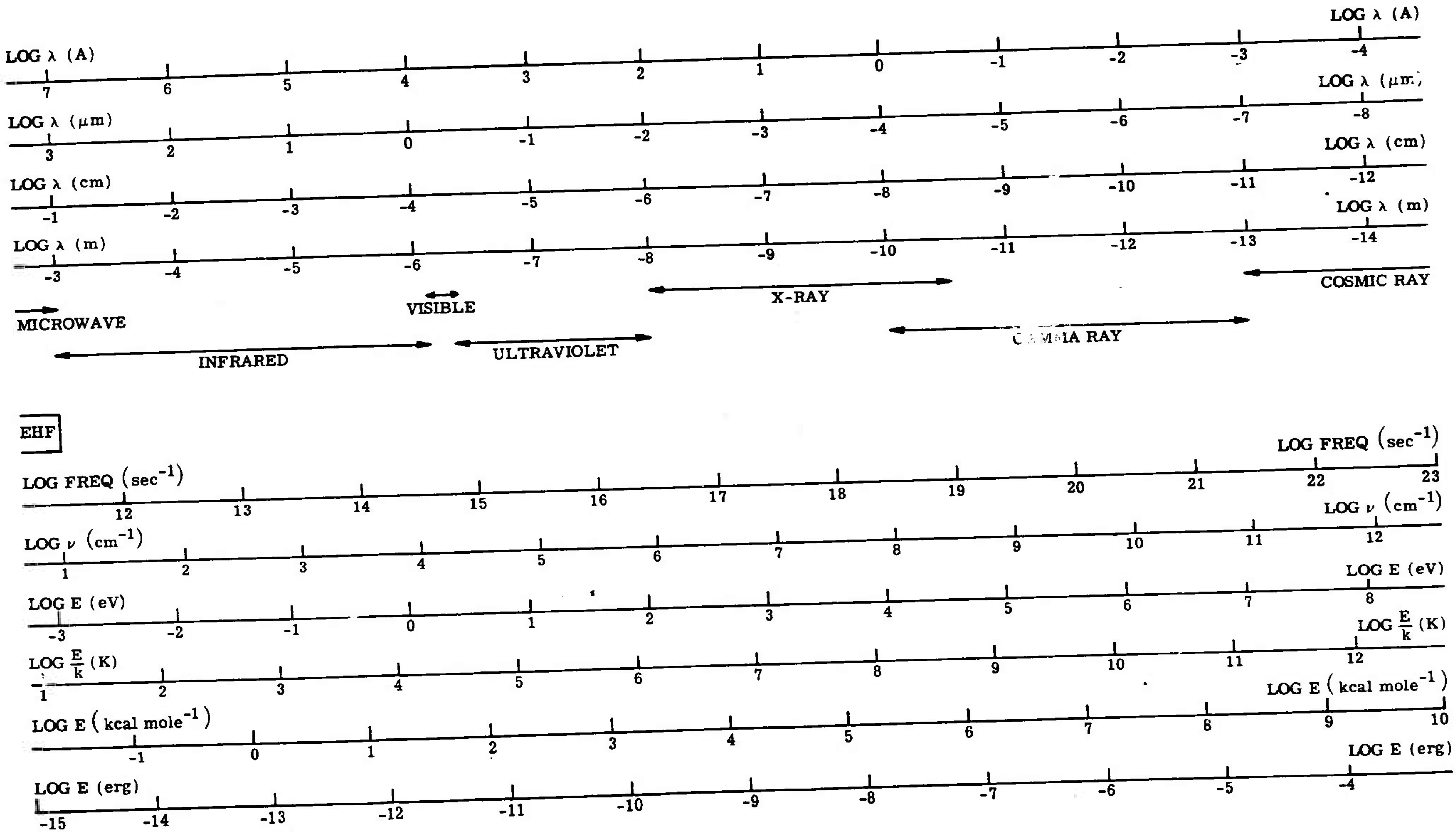
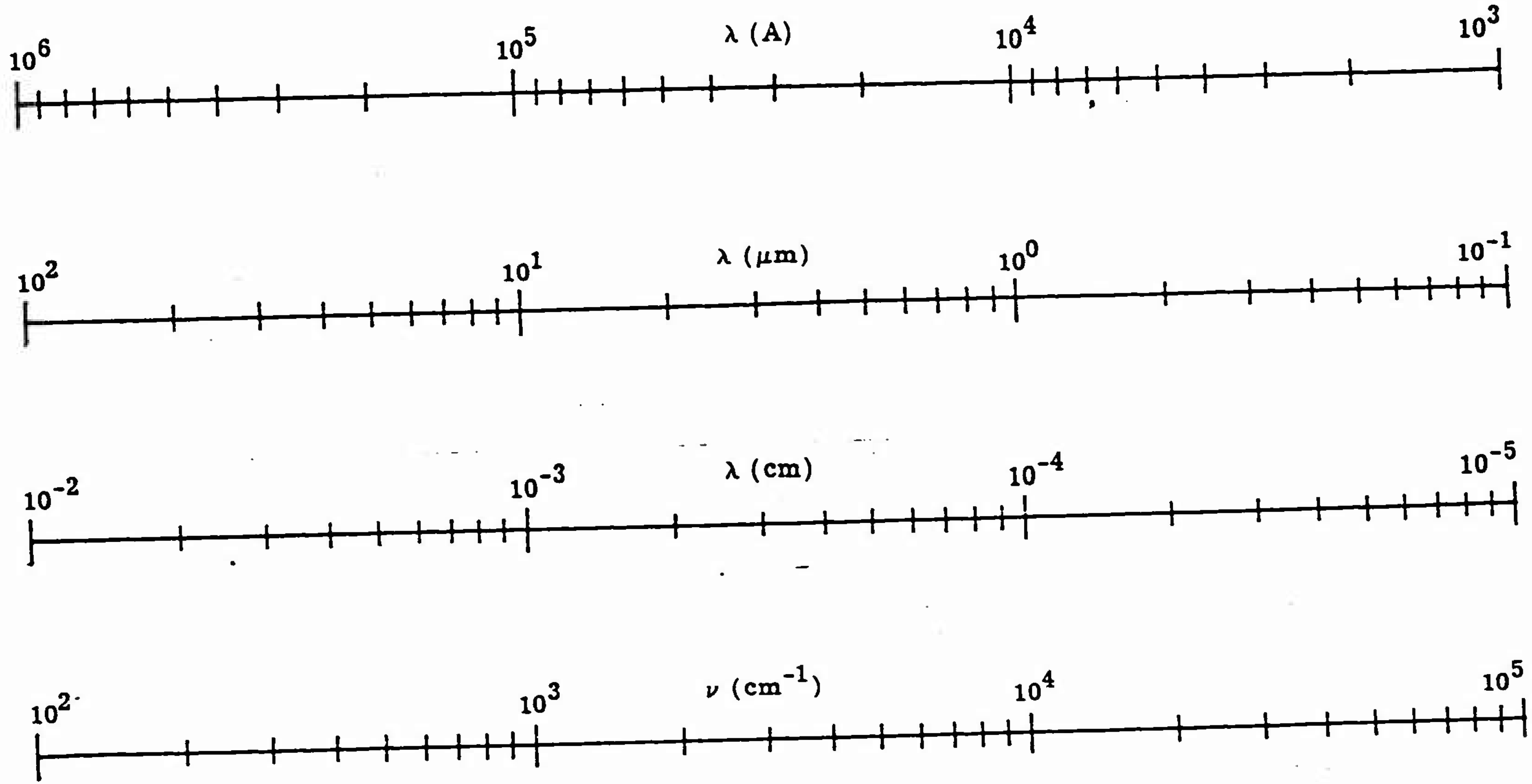
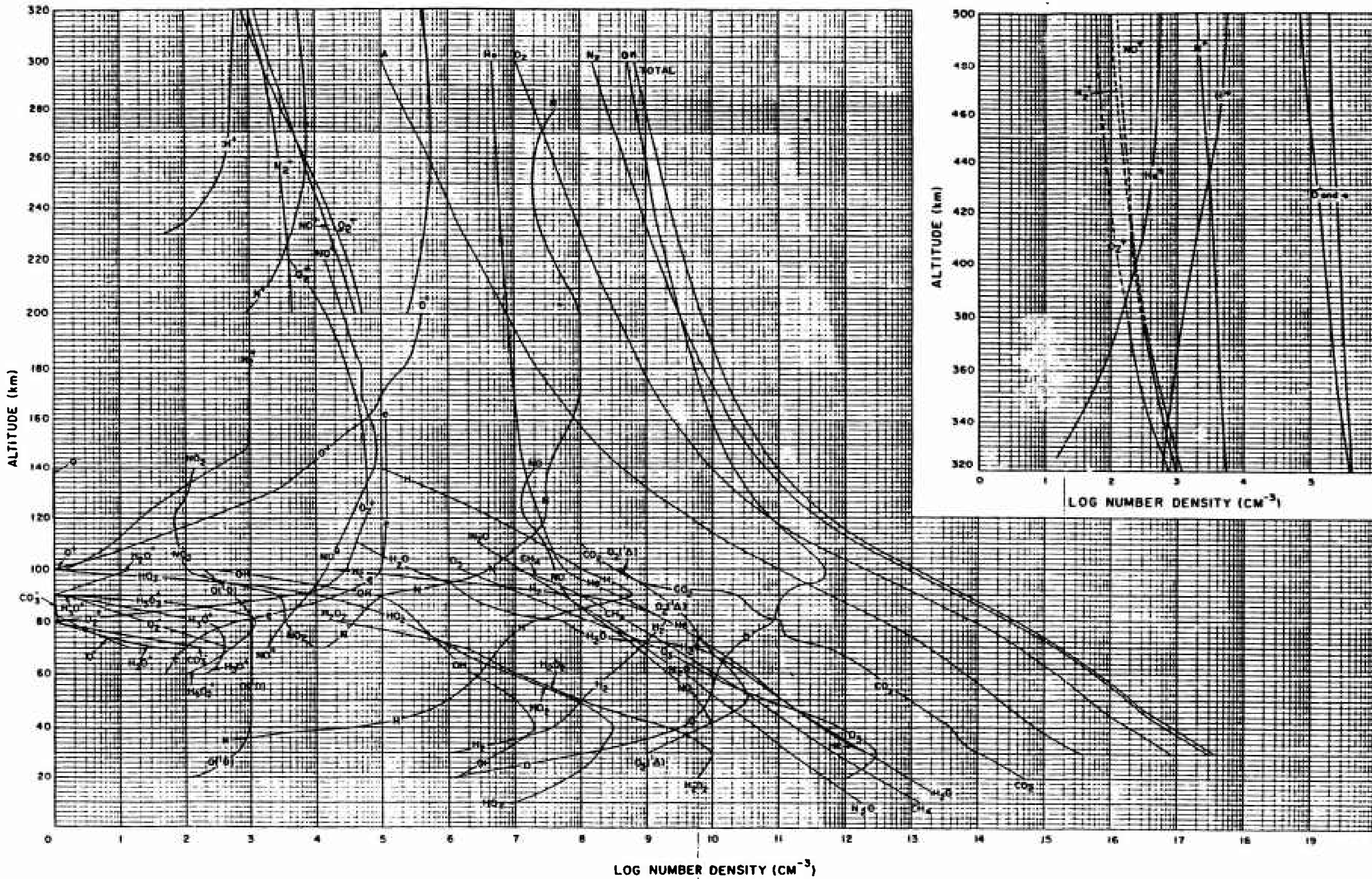


Table E.2-1. (Continued)

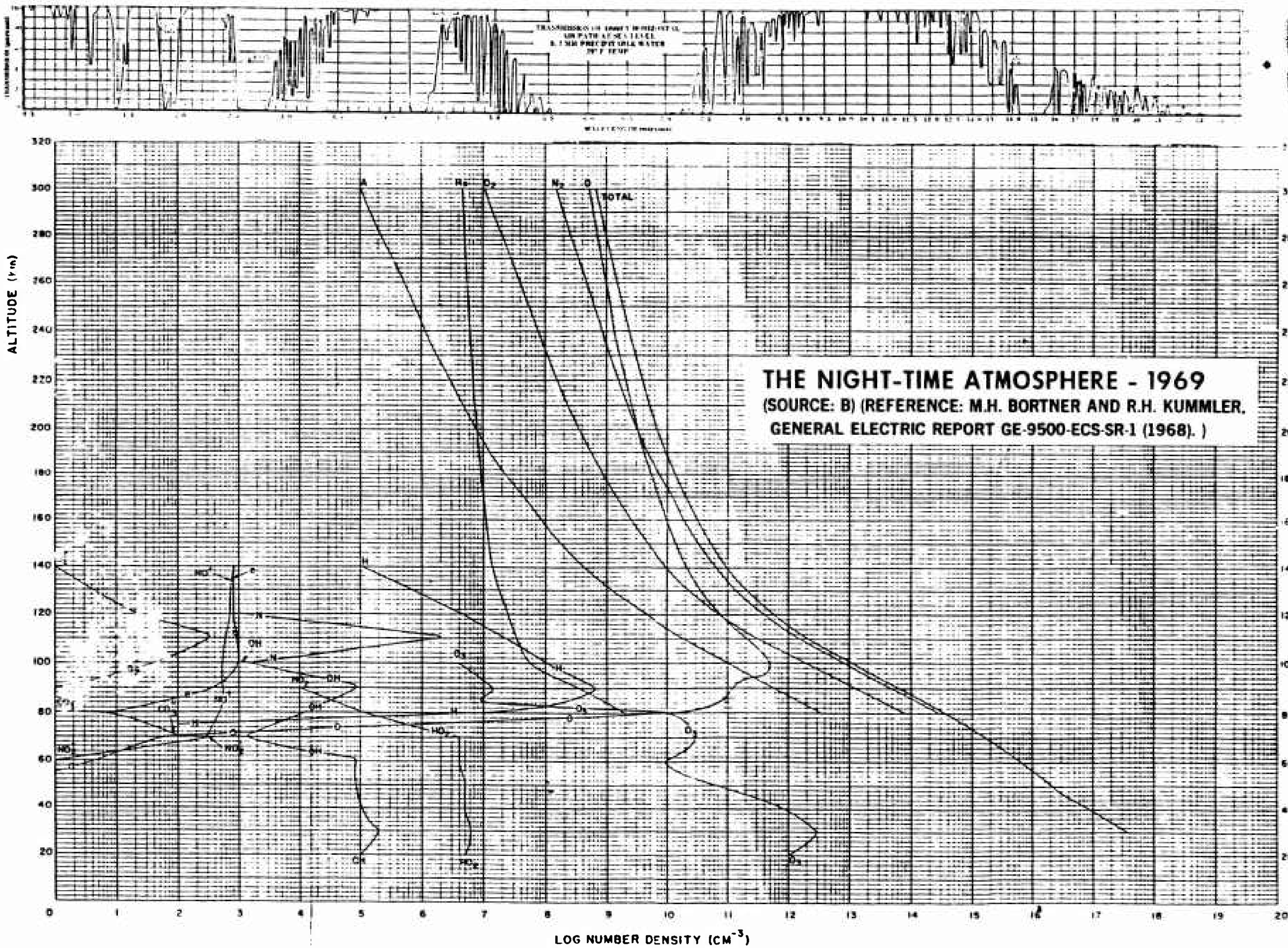
WAVELENGTH-ENERGY CONVERSION CHART (Mid-Range)





THE DAYLIGHT ATMOSPHERE – 1969

(SOURCE: B) (REFERENCES: M.H. BORTNER AND R.H. KUMMLER, GENERAL ELECTRIC REPORT GE-9500-ECS-SR-1 (1968); AND H.C. BRINTON et al., J. GEOPHYS. RES. 74, 2941 (1969).)



THE NIGHT-TIME ATMOSPHERE - 1969
(SOURCE: B) (REFERENCE: M.H. BORTNER AND R.H. KUMMLER, GENERAL ELECTRIC REPORT GE-9500-ECS-SR-1 (1968).)
ALTITUDE (km)
LOG NUMBER DENSITY (CM^{-3})
TOTAL